Indications for the selective prophylactic removal of mandibular third molar teeth

McArdle, Louis William

Awarding institution:
King's College London

Indications for the selective prophylactic removal of mandibular third molar teeth.

Mr Louis William McArdle

BDS, MSc (Med Sci), FDSRCS(Eng)

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The Book Worms

Through and through th’ inspir’d leaves,
Ye maggots, make your windings;
But O respect his Lordship’s taste,
And spare his golden bindings!

Robert Burns

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Acknowledgements.

When a man approaches middle-age and the ephemeral, or for some the perpetual mid-life crisis, a junction appears and a decision needs to be made as to which direction he will take. Shall he get fit, loose the waistline and acquire a mistress? Shall he buy the Maserati, put his foot down, and hope his wife doesn't notice that the car won't carry more than two? Shall he bumble along for the remainder of his career, losing the will to live and eventually retire with arthritis and an ever increasing and unhealthy cynicism about how your profession has been corrupted by the NHS? Or, do as I did, take the thoroughfare marked with both a question and an exclamation mark; or as my children proclaimed when I told the family – do a PhD?!

I had spent 10 years, along with a few others, getting the BAOS from a small peer group of oral surgeons to the established Association that it is today with over 400 members, its own Journal, and a bit of professional clout. During this time, however, I did not have the time to develop my career in the way in which I had wanted it to go. Along with getting the Association established and all the political lobbying that we had to do, I did not really have the time to focus on the other aspects of my career development. I had previously registered for a doctorate at my alma mater, however a change in job and the inability to find a suitable replacement supervisor put paid to that and my initial flurry into academia was quickly dowsed. At the end of my tenure with the Association it was time to do something professionally for me.

In 2000, NICE had carelessly given me the opportunity to get my teeth into (pun intended) the consequences of their own doing. No one was satisfied with NICE's guidance and over the first 10 years after the millennium I anecdotally observed these consequences in the form of distal cervical caries becoming a more common presentation amongst older patients. Hence the thesis that you are about to read.

Undertaking a PhD places many demands on many people not least of all family. A special thank you to my wife, Teresa, who has put up with 7 years of me coming home late of an evening, though I secretly think that she was glad of the peace and quiet. My two daughters, Ellie and Grace, both of whom have grown up into responsible and beautiful young adults during this time, and whose company is always a pleasure, especially when I'm paying. Each has contributed in their own way in giving me the space and opportunity to undertake this challenge – a big thank you to you all, especially my own mother who gave me all her brains as she keeps reminding me.

Thank you to Judith Jones, my second PhD supervisor, for her help and guidance – she may not feel that she has supported me enough but you have! In addition, a thank you to Manorahan Andiappan and Iftekhar Khan who helped me with the databases, statistical advice and answering all my statistics questions – I think I now know my mean from median from mode! My penultimate personal thanks to both Professor William Wade and Dr Erica Prosdocimi for their laboratory processing and analysis for the bacteriological samples. In addition, I would express my appreciations to my fellow consultants and registrars who have had to listen to my continuous pontificating in the office; the latter being the more captive audience!

A huge, sincere thanks to Fraser McDonald, my principal supervisor, who has advised and supported me through all this. I have always had a great professional admiration for Fraser and there was no one better qualified in my opinion who could, and would, provide the support needed in undertaking this academic task. Our bi-weekly PhD meetings were always interrupted by our joint clinic but we always found the time to see the patients as well. And why did I ask an orthodontist to be my principal supervisor? They are the only authority who can bond everything together and make things straight!

My father, Louie, died in 2017 and his influence on my professional career cannot be underestimated. He was a carpenter by trade and all the carpentry skills that he imparted to me have found their way into the surgical skill set that I have and into the skill sets of countless thousands of other dentists and oral surgeons that I have had the privilege to teach and tutor over the last 30 years. His great belief, imparted to him by his own father, was that everyone should have a trade. Once you have a trade, you can follow your dreams and do what every you want; knowing that your trade will always be there to fall back upon if those dreams don't become realised. His dream was to become a professional footballer and he won the under-21, Scottish Cup in 1954 with the Campsie Black Watch FC. Unfortunately, his football ambitions were ended with irreparable damage to his knee ligaments that eventually required a knee

replacement in later life. Fortunately, he did have his trade to fall back upon and was a well-regarded craftsman and gentleman. I remain very proud of him.

I, personally, have never really had any particular dreams nor ambitions out-with my professional career; perhaps it is time that I had, after all I've always got my trade to fall back upon….!

I think now is the time to take heed of that; many thanks for your advice, Dad.

Abstract.

The treatment or otherwise of third molars has been a controversy for a number of years. In 2000, with an emphasis on unnecessary financial costs, untoward patient outcomes and surgical morbidity, and a lack of evidence of any benefits to support prophylactic third molar removal, The National Institute of Health and Clinical Excellence (NICE) moved to eliminate the practice of prophylactic third molar removal from the National Health Service (NHS) with the introduction of its clinical guidance on the removal of wisdom teeth. This guidance led to a significant change in clinical practice in the UK and, as a consequence the practice of prophylactic third molar removal has been significantly reduced.

Following the introduction of NICE's guidance, the number of patients having third molars removed in secondary care decreased over the first 3-5 years of the decade. Third molar patient data sourced from the NHS Hospital Episodes Statistics (HES) databases determined treatment patterns for secondary care patients, and from the NHS Business Services Authority (NHSBSA) for primary care patients. For secondary care, patient numbers declined by approximately 30%, from a 90's decade average of 58k cases per annum, to a low of 39k cases in 2003. In primary care the number of mandibular third molars removed fell by 60% from an average of 77k mandibular third molars in the 90's to a low of 28k by 2004/5. Following this, and over the last 15 years, there has been a steady increase in the number of patients having third molar removal in secondary care from 39k cases per annum in 2003 to an average of 92k cases per annum for the three years of 2014-17: an increase of 136%. There is no comparable data for primary care in England as such data is no longer collected by the NHS.

Patients having third molars removed have been shown to be 4 years older on average; from an average age of 28 years in the 90's, to an average 32 years now. The pattern and nature of diseases indicating third molar removal have also changed. From 1995-2000 caries and its related disease, such as dental abscess and peri-apical infection accounted for 7% of all third molars removed. By the end of the first decade of the millennium caries and related disease was accounting for approximately 26% of all third molars removed: an increase of over 300%.

Third molar related caries can be classified in two ways. Impacted mandibular third molars (Md3M) can succumb to dental caries themselves, or contribute to the formation of distal cervical caries (DCC) on the adjacent mandibular second molar (Md2M). These two types of dental caries cannot be discriminated from the NHS databases and consequently the true frequency of third molar caries or Md2M DCC cannot be determined. Historically, Md2M DCC has been reported to account for less than 5% of all third molars removed. With the change in patient management brought about by NICE and the 300% increase in the frequency of caries related to third molars requiring removal, the frequency of Md2M DCC as the reason for third molar removal cannot be determined directly.

Approximately 90% of DCC lesions of the Md2M are seen related to mesio-angular impacted Md3M and 10% of lesions related to horizontal impactions. Md2M DCC now accounts for 14% of all Md3M removed but remarkably accounts for 44% of all mesio-angular Md3M removed and 60% of all mesio-angular Md3M in patients over the age of 30 years. It is estimated that approximately 23k patients per annum and 27k Md3M are removed per annum due to Md2M DCC, costing approximately £27m per annum to treat with additional potential costs of £28m if patients elected to have remedial implant treatment to replace second molars.

Md2M DCC as an indication for the removal of the impacted third molar challenges previous concepts and provides evidence for consideration of the prophylactic removal of Md3M.

Aims of studies

The aims of this thesis are to identify and evaluate the changes in third molar disease. Specific aims were:

- To identify if there has been a change in disease pattern following the introduction of NICE guidance.
- To determine if age, dental health, and the varying types of impactions alter the character of third molar disease.
- To determine if DCC can be predicted.
- To evaluate the costs to healthcare of current third molar treatment strategies in relation to Md2M DCC.
- To establish what type of bacteriological profile is found in the caries in distal cervical lesions of the Md2M.

The Null Hypothesis

In this series of studies, we have identified the null hypothesis is, that the introduction of NICE guidance has not affected the profile of disease or treatment of third molars.

Methodology and Data collection

- Literature search utilised online library resources including Ovid Medline (1974 to Dec 2018), Embase (1946 to Dec 2018) and Google Scholar. Principle medical subject headings (MeSH) search terms included: Molar, Third; Tooth/Teeth, Wisdom; Disease, Dental; Distal Cervical Caries; Guidelines, Third Molar; Clinical Indication; Prophylactic Removal. Inclusion criteria: English language articles. Exclusion criteria: non English language articles.
- Data collection in relation to the effects of NICE guidance was sought from Hospital Episodes Statistics (HES). Open access to data is available at HES online (https://digital.nhs.uk/data-and-information/data-tools-and-services/data-services/hospital-episode-statistics). In addition, diagnosis data for patients was formally requested from HES for evaluation. HES collects data for the NHS in England. Third molar data for Scotland; both secondary and primary care was requested from the Information Service Division for

NHS Scotland. Primary care data for England was accessed from the NHSBSA, formally the Dental Practice Board (DPB).

- Data extracted from HES referred to the Office of Population Censuses and Surveys OPCS classification of surgical operations and procedures version 4.6. Data included patients having procedure codes F0910 (removal of impacted third molar) and F0930 (removal of third molar). Procedure code F0920 (removal of impacted tooth) was excluded as this code is non-specific and includes removal of any impacted tooth.
- Data related to clinical diagnosis resulting in third molar removal is recorded but not reported online by HES. A special request was made to HES for all diagnostic data related to OPCS codes F0910 and F0930. Diagnostic data is recorded using the World Health Organisation (WHO) international classification of diseases (ICD) reporting codes.
- Third molar data for primary dental care was recorded by the NHS Dental Practice Board now the NHS Business Service Authority (NHSBSA) up until 2005 when the data recording process was reformed and exclude this level of recording. Codes for third molar removal are specific to both maxillary and mandibular third molar teeth. General Dental Services statement of dental remuneration codes 2203 and 2204 relate to the specific removal of impacted third molar teeth and can be linked to mandibular third molar teeth. Data was extracted from open access online datasets at the NHSBSA.
- Third molar data for Scotland was specially requested from the Information Service Division for NHS Scotland. As with HES, data related to procedure codes F0910 and F0930 and for primary dental care codes 2203 and 2204 was requested.
- For the clinical case-series of patients attending for third molar removal, a prospective database was created of patients over a two-year period. Data was collected over 2 years, 2013-15. This included all patients seen under my personal care for third molar removal undertaken in both primary care and secondary care, and included patients attending for treatment under local anaesthesia, local anaesthesia with sedation, and day-case general anaesthesia. Patient data was documented on a data recording proforma (see appendix I). Data recorded included patient identifier; patient gender as recorded on clinical

notes; age of patient at presentation; Decayed Missing Filled Teeth (DMFT) score: presence/absence of specific third molar based on FDI notation (18, 28, 38 ,48); eruption status of third molar (erupted, partially erupted, unerupted); angulation of third molar defined by convention (vertical, mesio-angular, horizontal, disto-angular or ectopic), whether removal of the third molar was indicated or not, and the clinical diagnosis for each individual third molar indicated for removal. Data was transferred onto an Excel master database and then anonymised to eliminate patient identifiers. Date was then analysed using IBM SPSS Statistics for Windows, version 23.0 (IBM Corp) and online statistical software MedCalc. In total, 1011 patients who had 1431 mandibular third molar removed were assessed. See appendix I for third molar study proforma.

- For clinical case-series data related to patients with Md2M DCC – two databases had been collated. 239 patients attending and diagnosed with Md2M DCC during 2011-13 had been collated (2013 cohort). This recorded an anonymised patient identifier, gender, age, DMFT score and angulation of the Md3M. This 2013 cohort were separate from the second cohort (2015 cohort) which was filtered from the master database of 1011 patients who included 180 patients who had Md3M removed due to Md2M DCC.
- Angulations of the third molar was defined by accepted standard convention. Third molars were categorised into vertical, mesio-angular, horizontal, disto-angular or ectopic impactions. Vertical was defined as the third molar having a vertical positional plane parallel to the relative vertical plane of the adjacent second molar; i.e. both second molar and third molar in the same vertical plane or long axis of third molar perpendicular to the occlusal plane through the premolar and molar teeth. Mesio-angular was calculation as the angulation of the occlusal plane of the third molar to the occlusal plane of molar and premolar teeth. This angle is the same as the angle between the long axis of the third molar and the second molar tooth. Horizontal was defined as the angulation of the occlusal plane of the third molar to the occlusal plane of molar and premolar teeth. This angle is the same as the angle between the long axis of the third molar and the second molar tooth. Intra-rater and inter-rater

reliability for assessing angulation of the third molar was assessed using Cohen's Kappa co-efficient.

- For the bacteriological study of Md2M DCC, caries and plaque was sampled from 16 patients who had their Md2M removed due to Md2M DCC. Caries was sampled from the DCC lesion of the extracted mandibular second molar and plaque was sampled from both ipsilateral and contralateral gingival crevices of the Md2M. Samples were cryogenically stored and processed to extract bacteriological DNA and results compared with Human Microbiome Database reference dataset.

Ethics:

Advice was sought from KCL Dental Institute ethics committee in 2012 (now Faculty of Dentistry and Oral & Craniofacial Sciences) regarding ethics application. Ethical advice was sought prior to the introduction of GDPR in 2018. For the clinical case-series database it was deemed that formal ethics approval was not required as no patient identifiable data would be retained or patient's treatment altered as a consequence of the data collection. For the bacteriological study of Md2M DCC, formal ethics approval was advised. Research ethics application was submitted via the online Integrated Research Application System (IRAS) and approved October 2015 (IRAS 14678), substantial amendment was applied for and approved September 2017. (See appendix II).

Statistics:

Patient age and the angulation of the mandibular third molar tooth were identified as the primary independent variables. Disease of the mandibular third molar was identified as the primary dependant variable. The original sample size was calculated by a power calculator (G*Power 3.1.5, Universität Düsseldorf), which allowed for a CI of 95% with a 5% margin of error (standard power level of 80% and alpha level of $p = 0.05$). A sample size of 969 was calculated, but 1011 patients with 1431 mandibular third molars indicated for removal were finally assessed. The sample and outcome characteristics were summarised using descriptive statistics. The mean age of the patients for different diseases and types of impaction were compared using one-way ANOVA. Significance was assumed at the 5% level, and analyses were done with the help of IBM SPSS Statistics for Windows, version 23.0 (IBM Corp) and online statistical software MedCalc.

List of abbreviations.

WHO – World Health Organisation

NICE/NIHCE – National Institute for Health and Clinical Excellence

NHSBSA – National Health Service Business Service Authority

HES – Hospital Episode Statistics

3M – third molar tooth/teeth

Md2M – mandibular second molar tooth/teeth

Md3M – mandibular third molar tooth/teeth

$_{\text{MA}}$Md3M – mesio-angular mandibular third molar tooth/teeth

$_{\text{DA}}$Md3M – disto-angular mandibular third molar tooth/teeth

$_{\text{HORZ}}$Md3M – horizontal mandibular third molar tooth/teeth

$_{\text{VERT}}$Md3M – vertical mandibular third molar tooth/teeth

$_{\text{VERT(imp)}}$Md3M – vertical impacted mandibular third molar tooth/teeth

$_{\text{VERT(non)}}$Md3M – vertical non-impacted mandibular third molar tooth/teeth

Mx3M – maxillary third molar tooth/teeth

DCC – Distal Cervical Caries

RCT – Randomised Control Trial

DPB – Dental Practice Board

OPCS 4.6 – Office of Population Censuses and Surveys. operation procedure coding system version 4.6

ICD-10 – International Classification of Diseases - volume 10

GDS – General Dental Services

SIGN – Scottish Intercollegiate Guidance Network

GA – general anaesthesia

NHS – National Health Service

SDR – Statement of Dental Remuneration

DMFT – Decayed/Missing/Filled Teeth

ADHS – Adult Dental Health Survey

OTU - Operational Taxonomic Units

APHA – American Public Health Association

ANOVA – Analysis of variation

AMOVA – Analysis of Microbial variation

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Appendix II.	**Md2M DCC bacteriological study; results protocols and IRAS application.**
Appendix III.	**Peer reviewed publications from this thesis:**

McArdle LW, Renton T. **The effects of NICE guidelines on the management of third molar teeth.** British Dental Journal. 2012; **213**(5): 434-440.

McArdle LW, McDonald F, Jones J. **Distal cervical caries in the mandibular second molar: an indication for the prophylactic removal of the third molar? Update.** British Journal of Oral and Maxillofacial Surgery. 2014; **52**: 185-189.

McArdle LW, Patel N, Jones J, McDonald F**. The mesially impacted mandibular third molar: the incidence and consequences of distal cervical caries in the mandibular second molar.** The Surgeon. Journal of the Royal Colleges of Surgeons of Edinburgh and Ireland. 2016; **16**(2): 67-73.

McArdle, LW, Andiappan M, Khan I, Jones J, and McDonald F. **Diseases associated with mandibular third molar teeth**. British Dental Journal. 2018; **224**(6): 434-440.

McArdle LW, Jones J, McDonald F. **Characteristics of disease related to mesio-angular mandibular third molar teeth.** British Journal of Oral and Maxillofacial Surgery. 2019; **57**: 306-311.

Chapter 1.

Introduction: Defining the third molar and the history behind NICE guidance on the management of third molar teeth.

1.1 Defining the third molar.

Third molar teeth are the last teeth to erupt into the mouth, normally between the ages of 18 and 24 years (Howe, 1985; Killey, 1975; Rantanen, 1967). Third molars can, naturally and uneventfully, erupt into a functional position. Others, however, will fail to erupt and remain impacted and unerupted within the jaw. Many will undergo eruption but fail to attain a functional position and thus become impacted in a partially erupted position (Kjær, 2014). The mandibular third molar is the most frequently impacted tooth in the jaw though impaction can occur with the maxillary third molar also. As a consequence, most published literature and comment regarding third molars relates to the mandibular third molar due to the variation and complexities of its impaction and the notable morbidity that it can cause.

The fully erupted third molar has the potential for normal function and longevity but may experience dental disease in a similar manner to the rest of the dentition. The unerupted and embedded third molar is unlikely to cause or experience disease although it may contribute to a relatively small incidence of dento-alveolar disease such as cyst formation. However, the partially erupted impacted third molar tooth is in an anomalous position that is compromised and has the greater potential to cause disease (Howe, 1985; Killey, 1975). The mandibular third molar is the most commonly impacted tooth in the jaw with the incidence of third molar impaction being as high as 70% in some population studies (Hashemipour, 2013; Venta, 2012).

The causes of third molar impaction are theoretical and attributed, in part, to a lack of available distal alveolar space for these teeth to erupt into. It is hypothesised that the long-term sociological change in diet from an abrasive type of diet to a contemporary, softer processed diet is responsible (Lombardi, 1982; Macho, 1992). Dental attrition will not only cause functional occlusal wear but will also result in interproximal wear between the teeth. Wear between the teeth, in this manner, should result in the creation of an interproximal gap, however physiological mesial drift of the dentition allows the teeth to move mesially thus maintaining contact with its neighbour. Inter-proximal wear is slow but continually occurs, resulting in the premolar and molar teeth drifting towards and assuming a more mesial position within the alveolus. This contributes to an increase in space distal to the second molar that is a factor in the development of space for the eruption of the third molar (Lombardi, 1982; Macho, 1992).

Furthermore, research also suggests that evolutionary changes in the human body have resulted in changes to the dental arches with shortening of the alveolus (Abu Alhaija et al., 2011; Tompkins, 1996). This is also considered to contribute to a lack of development of available alveolar space for third molar eruption (Abu Alhaija et al., 2011; Tompkins, 1996). Combined, both of these factors create a dysfunctional eruption process for the third molar, which results in failure of eruption and consequent impaction (Abu Alhaija et al., 2011; Lombardi, 1982; Macho, 1992; Tompkins, 1996). The significance of third molar impaction is recognised and categorised as a developmental disease by the World Health Organisation (WHO) in its classification of diseases (WHO, 2016). The definition of an impacted tooth as a developmental anomaly of the dentition results in the impacted third molar being, by default, the primary disease associated with the third molar.

An impacted third molar cannot and should not be singularly defined just as an impacted tooth. Dentists have recognised that the third molar exists in a variety of states: unerupted, partially erupted, and either functionally or non-functionally erupted. Depending on the age of the patient, it may be developing and unerupted or in older patients, either erupted or developmentally impacted and embedded. Spatially the tooth may be disorientated from a normal vertical position and angulation with recognised abnormal variations of angulation such as, mesio-angular, disto-angular, horizontal, inverted and ectopic (Howe, 1985; Killey, 1975). It is this wide variability of position, angle and state of eruption that gives an individual third molar its salient characteristics. These, in turn, affect the potential outcome for the third molar and the patient, either in a positive or negative manner. In addition, third molar teeth can be present in both the mandible and the maxilla and can display and contribute to similar yet differing clinical problems and disease.

Data presented in chapter two was collected from the NHS' online hospital episodes statistics datasets. This data collects information on how many patients had a third molar removed, however HES data does not distinguish between mandibular and maxillary third molar teeth. Reference to 'third molar teeth' is therefore collective to both mandibular and maxillary third molar teeth however over 90% of patients having third molar teeth removed have at least one mandibular third molar tooth removed (Worrall et al 1998).

1.2 Diseases related to third molars.

As stated, third molars in all three states of existence (unerupted, partially erupted and erupted), can experience a broad variety and spectrum of dental disease (Adeyemo et al., 2008; Anderson, 1998; Dogan et al., 2007; Forssel and Miettinen, 1988; Knutsson et al., 1996; Liedholm et al., 1999; Maurel, 1954; McArdle et al., 2018; Pratt et al., 1998; van der Linden et al., 1995).

Unerupted third molars can result in a number of diseases, such as cyst formation, internal resorption of the third molar and external resorption of the adjacent second molar. However, the incidence of these types of disease are extremely small and will often indicate the removal of the third molar. The limited potential for these diseases to occur cannot form any basis for the early removal of third molars to prevent them from arising (Friedman, 2007). With the incidence being so small the number needed to treat to prevent the development of such disease is so large and neither cost-effective nor cost-beneficial (Brickley et al., 1995; Edwards et al., 1999).

For the erupted and functional third molar, associated disease that can occur will often be the same diseases that can affect all the other teeth within the dentition. These diseases are namely dental caries, periodontal disease and their consequences. These types of diseases, however, are preventable with appropriate diet and effective oral hygiene and tend to be associated with older patients (McArdle et al., 2018).

The partially erupted impacted third molar is the most common third molar to require removal and accounts for the majority of third molars removed. This tooth is habitually inaccessible for adequate oral hygiene and consequently promotes and contributes to a variety of dental disease. The impaction, being considered as a developmental anomaly, may provide minimal clinical symptoms but can lead to secondary dental disease. The most common secondary disease associated with impacted third molars is pericoronitis; a local inflammation and infection of the surrounding operculum and gingival tissues of the third molar. It can vary in its clinical presentation and has many variants including subacute, acute, chronic and recurrent (Howe, 1985). In extreme forms it can lead to life threatening infections such as cellulitis, acute cervico-facial infections and sepsis. As with other teeth, caries and its related consequences (e.g.

pulpitis and abscess formation) can also affect the third molar. Although periodontal disease can be general and affect the dentition as a whole, it can also be localised to the third molar region and compromise the periodontal foundation of the second molar tooth (Elter et al., 2004a; Elter et al., 2004b).

Partially erupted third molars can be removed to facilitate other forms of treatment such as orthodontic/orthognathic considerations, trauma and tumour resection, however these indications are surgically specific and unique to individual patients and constitute a small proportion of third molars removed.

Critically, the partially erupted third molar can not only give rise to periodontal issues related to the second molar, but can also give rise to distal cervical caries on the adjacent second molar tooth (McArdle and Renton, 2006).

1.3 Incidence of third molar removal

Third molar surgery is one of the most common surgical procedures undertaken by the NHS in the UK and is also one of the most common surgical procedures in other developed countries around the world (McArdle and Renton, 2012; Renton et al., 2012). The exact number of patients having third molar removal in the UK is unknown due to the poor availability of data from all providers of third molar surgery (McArdle, 2013). For the period of 2016/17, conservative estimates suggest that approximately 152,000 patients had third molar teeth removed in England (McArdle et al., 2018). In England, approximately 93,000 patients were admitted to NHS hospitals for removal of third molar teeth in 2016/17, with an estimated cost in the region of £100m/annum (HES, 2018; NHS, 2014). This figure does not include patients having treatment undertaken under local anaesthetic in hospital, nor patients having treatment in primary dental care.

In North America, it is estimated that 5million patients/annum undergo third molar removal, with costs estimated at $3billion/annum (ADA, 1999; Eklund and Pittman, 2001; Friedman, 2007; Huang et al., 2014). Of all health insurance patients between the ages of 16-21 years 50% will have had third molar removal undertaken (Friedman, 2007; Friedman, 1983). Critics have questioned the significant volume of third molar removal undertaken and ask why so many third molars are removed and particularly whether the removal of so many third molars is indicated and justified (Friedman, 2007; NICE, 2000; Song et al., 1997; Song, 2000).

Third molar teeth often cause problems for patients and are commonly removed as a consequence of dental diseases (Liedholm et al., 1999; Precious, 1992; van der Linden et al., 1995). Historically, however, it was common practice for dentists and oral surgeons to undertake the removal of impacted third molar teeth in younger patients before disease and symptoms could arise and therefore eliminating the potential for disease (Friedman, 1983; AAOMS, 2013). The basis of this was the implied perception that the impacted third molar would frequently cause disease and should be considered for removal as soon as possible. In essence the impacted third molar, in isolation, was an indicator for removal whether associated with disease and symptoms or not. This practice of early prophylactic third molar removal had been relatively universal in most developed countries with historical reports of over 40% of all third molars removed in the UK having no clinical indication for removal and subjected to prophylactic removal (NICE, 2000; Song et al., 2000). In the USA, 70% of all third molars subjected to early removal have been reported to be disease free (Friedman, 2007).

Critics noted that there was no evidence to demonstrate that any particular impacted third molar would cause disease and that prophylactic third molar removal should be discouraged and contraindicated (A.P.H.A., 2008; Brickley et al., 1990; NHS Centre for Reviews and Dissemination, 1998; Friedman, 1983; NICE, 2000). Clearly, one of the major aspects of this criticism is the inability to predict which third molars will lead to clinical problems (FDSRCS(Eng), 1997; Mettes et al., 2008; Song et al., 1997).

1.4 Cost implications

Prophylactic third molar removal has consequences in terms of financial, social and health costs. It was estimated that for England, based on calculations made from data of 1999 that £4million/annum could be saved. In the USA, based on calculations from 2006, $2billion/annum could be saved by not removing disease free impacted third molars (Friedman, 2007; NICE, 2000). The debate and controversy concerning prophylactic third molar removal is not just isolated to the United Kingdom and USA. The practice has also been widespread in Europe, Oceania, Africa and the Americas (AAOMS, 2013; Adeyemo, 2006; Inst German Dentists, 2010; Dodson, 2010; HTA, 2010; Knutsson et al., 2001; Stordeur, 2012).

For individual patients, costs are measured in terms of post-surgery disability in time off work, reduced productivity and loss of earnings; and in terms of potential clinical and morbidity outcomes such as post-operative debilitation and complications such as nerve injury (Friedman, 2007; Mercier and Precious, 1992; NICE, 2000). In the USA, for example, it is estimated that up to 25,000 patients per annum experience avoidable permanent nerve injury as a result of unnecessary third molar removal (Friedman, 2007). Third molar removal costs money, which providers have to pay for and patients are subjected to potentially unpleasant and questionably unnecessary surgery which can result in significant morbidity. As a consequence, there is an element of suspicion on dentists and oral surgeons, as to the motivation for continuing the practice. With oral surgeons in the USA earning in the region of $500,000/annum from third molar removal alone, there is also further suspicion by healthcare providers of the probity of the dental profession in relation to this practice (Friedman, 2007). With all the variety of costs involved and no proven benefits of prophylactic removal – can it be justified?

It is not controversial to acknowledge that prophylactic third molar removal had been standard practice, along with symptomatic removal in the past, and this essentially qualifies the criticism related to the significant volume of third molar removal undertaken (Friedman, 2007; Song et al., 1997; Song et al., 1999). Criticism of prophylactic third molar removal has therefore been significant yet there has been an overwhelming failure within the dental profession to properly justify this practice with evidence to show that there is any benefit to support it (Friedman, 2007; Ghaeminia et al., 2016; NICE, 2000; Song et al., 2000). Prophylactic removal has been controversial because the clinical evidence to support early removal has been lacking and is based primarily upon consensus expert opinion (Friedman, 2007; NIH, 1980). In this era of evidence based medicine however, clinical practice has to be supported by high quality evidence, not solely from expert opinion (Keeley, 2003). It is not that clinical research demonstrates that prophylactic removal is inappropriate; it is merely that appropriate clinical research has not been undertaken to support prophylactic intervention and consequently does not exist (Ghaeminia et al., 2016; Mettes et al., 2008; Mettes et al., 2012).

This significant lack of evidence is, however, counterbalanced by the complexities of undertaking clinical research to ascertain if prophylactic third molar has a role to play as the type of research required would be impractical to undertake and probably unethical. Consequently, prophylactic third molar removal is shrouded in controversy as there is no way to refute it nor support it (Mettes et al., 2012).

The concept of evidence based practice is the modern model in the delivery of healthcare whereas historically the majority of clinical interventions and treatments were consensus based as conceptualised by the Bolam principle of clinical practice (Bolam v Friern HMC, 1957; Sackett et al., 2000). Evidence based practice is reliant upon on empirical clinical research as the foundation of good clinical practice rather than the Bolam principle where the consensus opinion of a learned body of professionals defines what good clinical practice is (Bolam v Friern HMC, 1957; Sackett et al., 2000). Consensus opinion has been shown to be wrong in the past as a result of systematic clinical research and the resultant evidence that then changes practice. Gastric & duodenal ulceration was commonly treated with a variety of invasive gastro-intestinal surgical procedures until the cause of such ulceration was found to be bacterial in origin and the condition is now treated with simple antibiotics (Adkins et al., 1985; Malfertheiner et al., 2006). Likewise, congenital talipes equinovarus (club foot) was previously treated with complex surgery until it was superseded by the non-surgical Ponseti method (Bridgens, 2010).

Clinical research may provide the evidence base for consensus opinion resulting in parity of both, however, in the case of third molar management, there is a lack of clinical research and evidence base to ascertain whether prophylactic third molar removal has any benefit (Ghaeminia et al., 2016). This lack of evidence has become the main driver of third molar clinical practice, led not so much by clinicians but by third party administrators and commissioners. Consequently, prophylactic third molar removal is now generally proscribed in the UK (NICE, 2000).

A criticism of evidence-based practice is that it can demonstrate subliminal bias towards clinical outcomes for population groups of patients rather than for individuals (Sackett et al., 2000). Its doctrine is often what is best for the majority and what is the most cost-effective form of healthcare where healthcare budgets are finite, for example in the use of controversial and expensive cancer drugs. Evidence-based practice does not necessarily recognise and accommodate the patient as an individual, in that evidence-based practice offers solutions for the majority rather than a bespoke and tailored solution for an individual: the two do not necessarily go hand-in-hand. It is fundamental that all medical interventions need to be supported by clinical evidence but tailored to the individual patients needs and expectations: both are synonymous with the other.

The practice of prophylactic third molar removal has been based primarily on the consensus opinion of the profession as it was generally considered that the probability of successful third molar eruption and function was unlikely and that early prophylactic removal would eliminate the consequences of failed eruption, i.e. impaction, disease and clinical symptoms (Friedman, 2007; Friedman, 1983; NIH, 1980). Although it is accepted that an impacted third molar can result in disease; that in turn will lead to its removal, it is unclear, however, as to whether all developing third molars will become impacted and result in disease (Brickley, et al., 1996; Friedman, 2007; Ghaeminia et al., 2016; Song et al., 2000). For those that do become impacted the question of, if, when and what type of disease will result and necessitate the removal of the third molar is also unclear. In addition to non evidence-based consensus opinion, researchers in the past have attempted to justify the prophylactic removal of third molars based on the potential local periodontal outcomes of third molar impaction, in that periodontal disease has a correlation with cardiovascular disease and other systemic diseases (Beck et al., 2001; Elter et al., 2005).

The removal of third molar teeth as a universal health provision in the absence of disease is financially expensive, and can be argued to be unnecessary and a waste of healthcare resources - how can any benefit be perceived, justified and measured before any disease occurs and is realised? (Friedman, 1983; NICE, 2000; Shepherd et al., 1994b). Intervention should target disease, or substantial high risk of disease, rather than an unknown potential for disease unless it can be accurately predicted.

Prevention of disease is always better than cure but disease prevention in the form of a surgical intervention has a contentious cost-benefit value as the financial cost can be significant and can also have non-beneficial and unfavourable outcomes in the form of surgical morbidity (Bramley, 1981; Brann et al., 1999; Brickley et al., 1996; Friedman, 2007; Venta et al., 2014). Although a positive benefit to the individual can be claimed and realised, irrelevant of cost, the collective financial cost to society as a whole can be excessive and disproportionate (Friedman, 2007; HTA, 2010; NICE, 2000). In defining and measuring a positive cost-benefit of an intervention, the said intervention should ideally have a small cost and a significant benefit for the individual and society as a whole (Jamison et al., 2006). For example, national immunization programmes for infectious diseases such as polio, diphtheria, measles, mumps, rubella, and human papilloma virus are relatively inexpensive interventions on an individual level that collectively offer protection for society as a whole (Zhou, 2014). Although these diseases can be relatively minor, exceptional complications can arise leading to life changing issues for those not immunized and subsequently infected. The cost-benefit to society of these immunisation programmes outweighs societies financial cost of implementation and cost of treating such diseases and complications and for the individual avoidance of disease and rare but life changing complications.

In dentistry the model of prevention being better than cure is universally accepted. Preventive dentistry in its many forms has vastly improved the dental health of the population with patients retaining more of their teeth for longer (ADHS, 2000; ADHS, 2011). It could be argued that the prophylactic removal of third molar teeth is a form of preventive dentistry, where the impacted third molar is removed before it causes problems. Whereas the use of fluoride and good oral hygiene techniques, for example, are minimally invasive, self-administered and hugely cost-effective, prophylactic third molar removal could be considered significantly invasive and, by its nature, high in monetary cost, requiring significant surgical training and potentially high in patient morbidity (Friedman, 2007; Hill, 2006). The removal of third molars is expensive and can cost up to £1200 per day-case on the NHS and £3000 from private providers (NHS, 2014). The cost-effectiveness of prophylactic third molar removal has been deemed to be questionable from both a financial and clinical perspective as there is no comprehensive evidence to support it (Ghaeminia et al., 2016; NICE, 2000; Song et al., 2000). However, prophylactic surgical intervention is not a practice isolated to dentistry: prophylactic mastectomy in individuals with BRAC-1 gene to reduce the risk of breast cancer and bariatric weight-loss surgery as a supplemental indication for the prevention and reversal of type II diabetes in clinically obese patients have been prominent in the popular press as well as the scientific literature (Buchwald, 2009; Rebbeck, 2004). Prophylactic surgery does appear to have a role to play in the management of patients however qualifying its place is not so straightforward.

1.5 NICE Guidance

In 2000, with an emphasis on unnecessary financial costs, untoward patient outcomes, a growing criticism questioning prophylactic third molar removal and a lack of evidence of any benefits to support it, The National Institute of Clinical Excellence moved to eliminate this practice of prophylactic removal from the NHS with the introduction of clinical guidance on the removal of wisdom teeth *sic* (NICE, 2000). This guidance has led to a significant change in clinical practice in the UK and, as a consequence the practice of prophylactic removal within the NHS and medical insurance sector has largely ceased. The effects of this guidance and the moratorium of prophylactic removal has had significant and unforeseen consequences for the patient, the NHS and the dental profession.

1.5.1 Background

Clinical guidance on the removal of wisdom teeth was published in 2000 (NICE, 2000). The main driver for this was the perception that in the UK up to 44% of all third molars removed were disease free and consequently had no clinical indication for removal. (NICE, 2000; Song et al., 1997; Song et al., 2000) NICE based its guidance on a report they commissioned from the University of York's NHS Centre for reviews and dissemination which was published in 2000 (Song et al., 2000). Although the principle aim of the report was to look at the effectiveness and cost-effectiveness for prophylactic third molar removal, the report focussed on the evidence related to third molar surgery and the lack of high quality evidence that supported prophylactic removal.

In the 90's there was growing criticism regarding the seemingly unnecessary volume of third molar removal being undertaken in the UK (Brickley et al., 1996; Shepherd, 1993; Song et al., 2000). Studies being undertaken demonstrated that a significant proportion of patients were having asymptomatic, disease free third molars removed which was, in essence, an unnecessary use and waste of NHS resources. In a review of 500 patients having third molars removed, Brickley and Shepherd (1996) demonstrated that only 59% of third molars removed had a defined clinical indication for removal based on the criteria established by the National Institute of Health in the USA: in essence 41% of third molars had no clinical indication for removal (Brickley et al 1996; NIH, 1980). In addition to the 41% of third molars reportedly removed unnecessarily they also observed that 34% of the patients had no clinical indication for the removal of any of their third molars and consequently underwent unnecessary and apparently needless surgery (Brickley, et al., 1996).

In 1995, the British Association of Oral & Maxillofacial Surgeons undertook a national audit of third molar surgery and their findings were reported in 1998 (Worrall et al., 1998). Approximately 8000 patients were included in this audit with 25,000 third molars assessed and approximately 20,000 subsequently removed. Based on NIH criteria, it was reported that 44% of these third molars were disease free (Song et al., 2000; Worrall et al., 1998). This evidence would appear to be the source of NICE's observation of third molar practice and prophylactic removal, and justification for the consequent proscription of prophylactic third molar removal (Song et al., 2000; NICE, 2000). In this author's opinion, Song's and NICE's focus on the 44% of third molars that lacked a clinical indication for removal creates a myopic perspective on the audit's conclusions and overlooks additional salient facts derived from the national audit that should be put into perspective.

The national audit assessed both maxillary and mandibular third molars that had been removed with most patients having had their third molars removed under general anaesthesia. Historically, it was common practice to remove asymptomatic teeth that had potential to become diseased to avoid further surgery at a later occasion especially under general anaesthesia (Brickley et al., 1996). Analysis of the 44% of disease free third molars removed demonstrated that 79% of these were maxillary third molars and 21% were mandibular third molars (Worrall et al., 1998).

Maxillary third molars accounted for the majority of asymptomatic third molars removed. Maxillary third molars were commonly removed as the loss of the mandibular third molar would often lead to the overeruption of a retained non-functional maxillary third molar. This would consequently lead to clinical problems and symptoms which would result in subsequent removal. Previously, the accepted tenet was to remove the maxillary third molar at the time of mandibular third molar removal as the maxillary third molar is usually simple to remove, adding minimal additional time to the procedure, with minimal post-surgical morbidity, generally masked by the post-surgical morbidity of the mandibular removal.

Worrall's analysis could be described as somewhat overcomplicated but further analysis of the data suggests that all patients who had disease free third molars removed also had diseased third molars removed. In essence no patient had solely disease free third molars removed; vis-a-vis all patients had at least one symptomatic tooth removed as part of their treatment. Although 44% of all third molars removed were disease free and did not have a defined clinical indication for removal, 100% of the 6,000 patients who had their third molars removed had at least one diseased third molar (Worrall et al., 1998). There is a subliminal conclusion to be drawn that possibly 44% of all patients had no indication for any treatment at all.

It could be asserted that 44% of patients did have additional third molar surgery at the same time as indicated third molar surgery. Defining whether it was wholly unnecessary is a point for debate and not necessarily monochrome in explanation: the question is multifaceted. Undertaking additional treatment may expose the patient to additional morbidity and the additional risk of adverse complications, however clinical risk and outcomes, both positive and negative, have to be weighed up against the overall benefit, not only for the patient, but for limited and finite resources of the NHS. Furthermore, additional third molar surgery is not proposed without due consideration by the clinician and the prior informed consent of the patient and more importantly but less appreciated is that it does not have any direct additional cost implications to the NHS if undertaken as a single course of treatment as is the case with treatment under general anaesthesia.

In the NHS, the cost for third molar surgery in secondary care, and more recently in primary care, are remunerated on a 'course of treatment' basis (NHS National Tariff payment system, 2014; NHS England IMOS contract, 2014). In effect, the cost of treatment is the same whether one third molar is removed or all four are removed, when carried out in a single course of treatment. What does cost the NHS more, is patients having multiple courses of treatment spread out over separate periods. If four third molars are removed over different treatment episodes then this will attract four separate fees for each of the third molars removed (NHS, National Tariff Payment System 2014; NHSBSA, Satement of Dental Remuneration 2005; NHSEngland IMOS contract 2014). This will increase the cost to the NHS over time and it does not require a complex cost-benefit or cost-effectiveness study to demonstrate that it is more expensive to treat four third molars on four separate occasions than to treat all four third molars in a single treatment episode. Where the cost of treatment can be concentrated and isolated to one single treatment episode then it will always be more cost-effective. From a consumer perspective it is always more cost-effective to buy four for the price of one rather than the contrary. There is anecdotal evidence that the increase in the number of patients having third molar surgery over the last 15 years is due to patients being subject to multiple treatment episodes over long time periods due to the asynchronous nature of the presentation of disease affecting individual third molars in a single patient.

In the late 90's the NHS commissioned the NHS Centre for Reviews and Dissemination at the University of York to undertake a review of third molar surgery to look at the relative effectiveness and cost-effectiveness of prophylactic removal. This review was led by Song who initially reported in 1997 and finally in 2000 in the NHS R&D Health Technology Assessment report (Song et al., 1997; Song et al., 2000).

Song undertook a review of the available literature with the aim of providing a summary of evidence related to prophylactic third molar removal (Song et al., 2000). Forty studies were identified that fulfilled the search criteria of randomised control trials (RCTs), literature reviews and decision analysis studies. Of the two RCTs identified, one was still ongoing and the second was an orthodontic RCT which dwelt on the variation of incisal crowding in patients who had third molars prophylactically removed as part of orthodontic treatment and those that had not (Harradine, 1998; Vondeling, 1999). Vondeling undertook an RCT comparing the effects and costs of prophylactic third molar removal and symptomatic third molar removal according to morbidity. This study, of less than 200 patients over a 4 year period concluded that non-intervention may be better, however the longer follow up of patients would be required to evaluate adequately (Vondeling, 1999). Realistically, the time period of this study was insufficient and the number of recruits relatively small to draw any significant conclusions, either preliminary or final. Although the conclusions drawn were preliminary the study does not appear to have been followed through to a final end point and consequently no conclusion can therefore be made regarding the original study.

The inclusion of Harradine's study seems inappropriate as this RCT looked at a very narrow and specific outcome which is irrelevant to the principal question related to prophylactic third molar surgery and the nature of third molar disease (Harradine, 1998). The variability of lower incisor crowding secondary to third molar retention versus removal is a specific clinical outcome for orthodontists and has, arguably, minimal significant clinical or practical relevance for either patients and clinicians. Although it is an RCT related to third molars, it does not address the fundamental questions of prophylactic third molar removal, which is whether early asymptomatic removal is better than symptomatic removal for a patient's overall well-being and for the payers of healthcare in relation to costs.

Finally, Song also includes a number of literature reviews and decision analyses in the review however most of these are criticised for poor study design and outcomes and ultimately not seen as strong enough evidence to provide a robust conclusion and recommendation for prophylactic removal (Song et al., 2000).

With a lack of evidence to support prophylactic removal a focus of the report is the substantiation by others that third molars are removed with no apparent clinical indication. With 44% of third molars from the BAOMS national audit having no indication for removal and the reported 41% from Brickley's study the observation and conclusion is that third molars are being removed unnecessarily and that patients are having treatment unnecessarily (Brickley et al., 1996; Worrall et al., 1998). This in turn, represents an apparent avoidable financial cost to the NHS and taxpayer and an apparent preventable burden of morbidity for the patient (NICE, 2000).

However, the results of Worrall and Brickley, that were used by Song appear to have been taken literally with no apparent appreciation of the underlying facts and nuances related to clinical practice. As discussed earlier, although 44% of third molars from the national audit may have had no clinical indication for removal, 100% of patients appear to have had at least one diseased and symptomatic third molar removed in conjunction with other asymptomatic teeth at no additional cost. This fundamental fact does not appear to have been appreciated either by Song or by NICE (McArdle, 2013; Worrall et al., 1998).

In the UK, Song's report is the main source of NICE's evidence and criticism of unnecessary prophylactic removal of third molars within oral surgery practice and forms the main reason by NICE for the proscription and moratorium on prophylactic third molar surgery (McArdle, 2013).

NICE's conclusion was that there is no evidence to support prophylactic third molar removal and recommended that only third molars with evidence of disease should be removed. A list of prescribed clinical reasons are shown in Figure 1.1 and these form the basis for the management of patients within the NHS (NICE, 2000).

Figure 1.1 Clinical Indications for the removal of third molar teeth as defined by NICE.

i. Pericoronitis (severe single, second recurrent).
ii. Unrestorable caries.
iii. Non-treatable pulpal and/or periapical pathology.
iv. Cellulitis, abscess and osteomyelitis.
v. Internal/external resorption of the tooth or adjacent teeth.
vi. Fracture of tooth.
vii. Disease of follicle including cyst/tumour.
viii. Tooth/teeth impeding surgery or reconstructive jaw surgery, and when a tooth is involved in or within the field of tumour resection.

Legend: *This table lists the clinical indications, as defined by the National Institute of Health and Clinical Excellence, for the removal of third molar teeth (NICE, 2000).*

1.6

NICE's guidance remains unchanged to this date and although at the time of introduction it attracted some individual criticism, the general response by the dental profession had been indifferent (Godden, 2000; McArdle, 2013). Critically, it remains unchanged and is still being used as the gold standard for management of patients with third molars within the NHS and also within the private healthcare sector. NHS commissioners are using the guide as a reference document for commissioning clinical services with only those fulfilling NICE's criteria being eligible for NHS treatment (NHSEngland, 2014). More disturbingly, anecdotal evidence suggests the NHS secondary care providers are also using them to manage already overloaded service waiting lists. Referrals are being vetted and patients who do not appear to fulfil NICE criteria being refused consultations to reduce pressure on clinic waiting lists and the 18-week pathway. In cases were complications have developed and litigation has resulted, non-conformity with NICE's guidance have been used to suggest breach of duty of care, clinical negligence and consequent liability (McArdle, 2013). In response to growing concern that NICE's guidance was having an untoward effect on patient management and dental health, NICE began a stakeholder review of its guidance in 2015 and a protocol for the review of the evidence was commissioned by NICE from the Liverpool Reviews and Implementation Group in 2016 (LRiG, 2016). For reasons unknown NICE have suspended this review and consequently NICE's guidance remains unchanged and continues to be contentious (NICE, 2017).

The consequences of NICE's guidance in the management of patients with third molars has been researched and published as part of this thesis, however one significant clinical observation after NICE's introduction was the observed increase in the frequency of caries arising in the distal cervical region of second molars as a consequence of the third molar impaction and retention (Allen et al., 2009; Chang et al., 2009; Falci et al., 2012; McArdle et al., 2006; Oderinu et al., 2012; Ozeç I et al., 2009; Toedtling and Yates, 2015).

The consequent formation of distal cervical caries necessitates the removal of the third molar to allow restoration of the second molar tooth and in some situations the loss of the second molar tooth as well. The location of the caries often dictates that restoration is generally complex and expensive especially if root canal treatment is indicated (McArdle et al., 2016).

If we consider that the third molar has had a definitive causal influence on the formation of distal cervical caries on the second molar and regress from this endpoint it would suggest that had the third molar been removed early, before the caries forms, it would have an overall benefit for the patient. This suggests a possible clinical indication for targeted prophylactic removal of mandibular third molar teeth (McArdle and Renton, 2006; McArdle et al., 2014).

Following the introduction of NICE's guidance in 2000, a fall of 30% third molar removal in secondary care, and a fall of 60% third molar removal in primary care, was observed over the first 3-5years in England. Following this, and over the last 15 years, there has been an increase of 136% in secondary care third molar removal (McArdle and Renton, 2012). Patients having third molars removed are now older on average, and the pattern and nature of diseases indicating third molar removal have also changed. Annually, from 1995-2000, caries and related disease accounted for approximately 7% of all third molars removed, however, by the end of the first decade of the millennium 'caries & related disease' was accounting for approximately 26% of all third molars removed: an increase in the region of 300% (McArdle and Renton, 2012; Renton et al., 2012).

Distal cervical caries of the mandibular second molar is an anomalous disease caused by retained impacted mandibular third molar teeth (Figure. 1.2) (Bruce et al., 1980; McArdle and Renton, 2006). Approximately 14% of all mandibular third molars are removed due to distal cervical caries on the second molar (McArdle et al., 2018). It only occurs in the presence of an impacted third molar and has been shown to result in the potential loss of up to 40% of all second molar teeth affected by it (McArdle et al., 2016). The development of mandibular second molar distal cervical caries challenges NICE's guidance and re-opens the debate on prophylactic third molar removal. mandibular second molar distal cervical caries is seen predominantly related to partially erupted mesio-angular impacted mandibular third molar teeth (MAMd3M) and in older population groups whose general dental health is better than average. (McArdle et al., 2019; McArdle and Renton, 2006; McArdle et al., 2014) It is seen to a lesser extent in partially erupted horizontally impacted mandibular third molar teeth as well but has not been seen in vertical or disto-angular impactions. (McArdle et al., 2019)

Figure 1.2 **Distal cervical caries (DCC) on the mandibular second molar (Md2M).**

Legend: *This radiographic image demonstrates: (i) dental caries formation on the distal cervical region of the mandibular second molar tooth secondary to the mesio-angular impaction of the third molar tooth, and (ii) dental caries formation on the third molar.*

This research was undertaken to evaluate the nature and characteristics of mandibular second molar distal cervical caries and to ascertain the consequences and costs of this. Furthermore, to ascertain the factors that will allow the risk of mandibular second molar distal cervical caries to be predicted, how it should be managed and discuss the case for selective prophylactic mandibular third molar removal.

Chapter 2

The effects of NICE guidance on the management of patients with third molar teeth.

Aspects of this chapter were published as:

McArdle LW, Renton T. **The effects of NICE guidelines on the management of third molar teeth.** British Dental Journal. 2012; **213**(5): 1-7.

2.1 Introduction

During the immediate years preceding the introduction of NICE's guidance the dental profession began to be challenged regarding the management of third molar teeth. Emerging published research and opinion questioned the perceived practice of prophylactic third molar removal which resulted in detailed scrutiny by NICE (Toth, 1993; NHS Centre for reviews and dissemination, 1998; Shepherd, 1993; Shepherd and Brickley, 1994a).

In 2000 NICE published its clinical guidance on the removal of wisdom teeth (NICE, 2000). As previously discussed, one of the main drivers for this was the observation by NICE and their commissioned review by the Health Technology Assessment programme at the University of York; that in the UK, up to 44% of all third molars removed were disease free and consequently had no clinical indication for removal (NICE, 2000; Song et al., 2000). The resultant recommendations directed that prophylactic removal of third molars should be discontinued within the NHS and that third molars should only be removed were disease indicated. The list of NICE's clinical indicators for third molar removal are tabulated in Figure. 2.1 and these form the basis for the management of patients within the NHS.

Figure 2.1 Clinical Indications for the removal of third molar teeth as defined by NICE.

<u>Clinical Indications for the removal of third molar teeth as defined by NICE.</u>

i. Pericoronitis (severe single, second recurrent).
ii. Unrestorable caries.
iii. Non-treatable pulpal and/or periapical pathology.
iv. Cellulitis, abscess and osteomyelitis.
v. Internal/external resorption of the tooth or adjacent teeth.
vi. Fracture of tooth.
vii. Disease of follicle including cyst/tumour.
viii. Tooth/teeth impeding surgery or reconstructive jaw surgery, and when a tooth is involved in or within the field of tumour resection.

Legend: *This table lists the clinical indications, as defined by the National Institute of Health and Clinical Excellence, for the removal of third molar teeth (NICE, 2000).*

NICE's guidance recommended changes to clinical practice in the UK with questioning of customary clinical practice for third molar removal, not only prophylactic removal, but also symptomatic third molar removal as well. Although NICE only covers clinical practice in England, it's influence guides clinical practice in Wales, Northern Ireland and Scotland. In Scotland, the Scottish Intercollegiate Guidance Network (SIGN) introduced its own guidance in 2000, however this is now redundant (SIGN, 2000).

2.2 Aims

The principle aim of this study was to identify the effects that NICE's clinical guidance on the management of third molar teeth has had on patients and clinical practice. In particular, what have been the changes in the annual number of patients having third molar teeth removed in England on a year-by-year basis over a 15-20 year period and what the primary clinical indicators and reasons for third molar removal were. In addition the trend in third molar removal in primary and secondary care in England was compared with Scotland.

2.2.1 Ethics

The KCL Dental Institute ethics committee was approached for advice regarding the need for ethical approval and as data collection would neither identify individual patients nor influence treatment or outcomes, formal ethical approval was not required.

2.2.2 Methodology

To identify the effects that NICE guidance has had on the management of patients with third molar teeth, data was collected to identify any changes in the annual number of patients requiring third molar removal and any variation in the nature of disease that had occurred. To ascertain the number of patients having third molar teeth removed, and the type of disease affecting third molars, data was gathered from the NHS from the following:

- Data collection in relation to the annual number of patients undergoing third molar removal in England was sought from Hospital Episodes Statistics (HES). This data was accessed from HES online at (https://digital.nhs.uk/data-and-information/data-tools-and-services/data-services/hospital-episode-statistics). In addition, diagnosis data for patients was formally requested from HES for evaluation. Third molar data for Scotland, both secondary and primary care, was requested from the Information Service Division for NHS Scotland. England primary care data was accessed from the NHSBSA, formally the Dental Practice Board (DPB).
- Data extracted from HES referred to the Office of Population Censuses and Surveys (OPCS) classification of surgical operations and procedures version 4.6. The total number of patients having procedure codes F0910 (removal of impacted third molar) and F0930 (removal of third molar) was calculated. The procedure code F0920 (removal of impacted tooth) was excluded as this code was non-specific and includes removal of any impacted tooth.
- Data related to clinical diagnosis resulting in third molar removal was recorded but not reported online by HES. A special request was made to HES for all diagnostic data related to OPCS codes F0910 and F0930. Diagnostic data was recorded using the World Health Organisation (WHO) international classification of diseases (ICD) reporting codes. All recorded ICD data related to OPCS codes F0910 and F0930 was calculated. All relevant subgroups of ICD diagnostic codes were categorised into the main ICD category including all subgroups of caries, periodontal disease and impacted teeth.
- Third molar data for primary dental care in England was recorded by the NHS Dental Practice Board now the NHS Business Service Authority (NHSBSA) up until 2005 when the data recording process was reformed and excluded this level of recording. General Dental Services statement of dental remuneration codes 2204 and 2205 related to the specific removal of impacted third molar teeth and can be categorised to both mandibular and maxillary third molar teeth. Data was extracted from open access online datasets at the DPB/NHSBSA.

- Third molar data for Scotland was specifically requested from the Information Service Division for NHS Scotland. As with HES, data related to procedure codes F0910 and F0930 and for primary dental care codes 2203 and 2204 was requested.
- All data extracted was collated on Excel spreadsheets and evaluated to ascertain the annual number of patients having third molar removal. Principal diagnostic data was collated and recorded as the proportion of all third molar disease on an annual basis.

Data to establish what changes NICE may have had on third molar management are available through national NHS data records. The NHS manages a number of separate databases that record varying parameters that can be accessed and from these we can identify the annual trends in clinical practice as it relates to third molar removal. NHS Hospital Episodes Statistics (HES) online (England); the NHS Business Service Authority (NHSBSA), previously the Dental Practice Board (DPB); and data from NHS Scotland's own databases, provide global records of service delivery within the England and Scotland (HES, 2018; NHS Scotland, 2012; NHSBSA, 2006). Amongst other things, HES's data records the annual number of patients having a specific surgical procedure undertaken: these are recorded based on the NHS's Operative Procedure Coding System version 4.6 (OPCS 4.6 codes) (NHS OPCS, 2016). The OPCS Codes used by HES for third molar surgery are F0910 (removal of impacted third molar tooth), and F0930 (removal third molar tooth). In addition, HES records the primary diagnosis based on the World Health Organisation's International Classification of Diseases, version 10 (WHO ICD-10 codes), that indicates such a clinical intervention (WHO, 2016). Up until 2005 and the introduction of the new NHS General Dental Services (GDS) contract, the DPB recorded the actual volume of third molar teeth removed. Third molars were ascribed specific codes as part of the NHS General Dental Services (GDS) contract (GDS codes 2204/5). In Scotland, the management of NHS dental services is different from England however similar databases record the same information. Data analysis of these databases allowed comparisons of the volume of third molar surgery undertaken in both primary and secondary care settings on a year-by-year basis. In addition, it will allow assessment of the nature and range of third molar disease.

HES data is available online at https://digital.nhs.uk/data-services/hospital-episode-statistics where main surgical procedures can be traced and summative totals calculated for third molar removal in England. Data for GDS third molar procedures is available from the NHSBSA dental services at http://www.nhsbsa.nhs.uk. Data from NHS Scotland was supplied by the information services division NHS Scotland, Edinburgh.

It is important to appreciate that the data recording by HES and the DPB/NHSBSA are different. Patients may have more than one third molar removed during a course of treatment and if one does not appreciate the nuances of data recording by these systems then the interpretation could be confusing. HES records the ***number of patients*** that have had one or more third molars removed whereas the DPB records the actual ***number of third molars*** removed. Consequently, from HES data we do not know how many third molars were actually removed and conversely from the NHSBSA/DPB data we do not know the actual number of patients who had third molars removed. Because of this more third molars could be being removed in secondary care than the data would suggest as patients may have had more than one third molar removed. Conversely the numbers of third molars being removed in primary care does not reflect the total number of patients for the same reason and this has to be taken into consideration in collating, analysing and interpreting the data. Primary care data has been limited to mandibular third molar removal, as this specific data can be isolated by the NHSBSA. Secondary care HES data records the number of patients who have an OPCS coding of F0910 or F0930. These codes relate to the removal of third molars but do not identify whether the third molars are maxillary or mandibular, however most problematic impacted third molars that are removed are mandibular (Worrall et al., 1998).

2.2.3 Statistical analysis

Statistical evaluation of data was limited to basic descriptive statistics, total number of patients undergoing third molar removal, or number of Md3M removed on an annual basis, mean age of patients and frequency of disease on an annual basis.

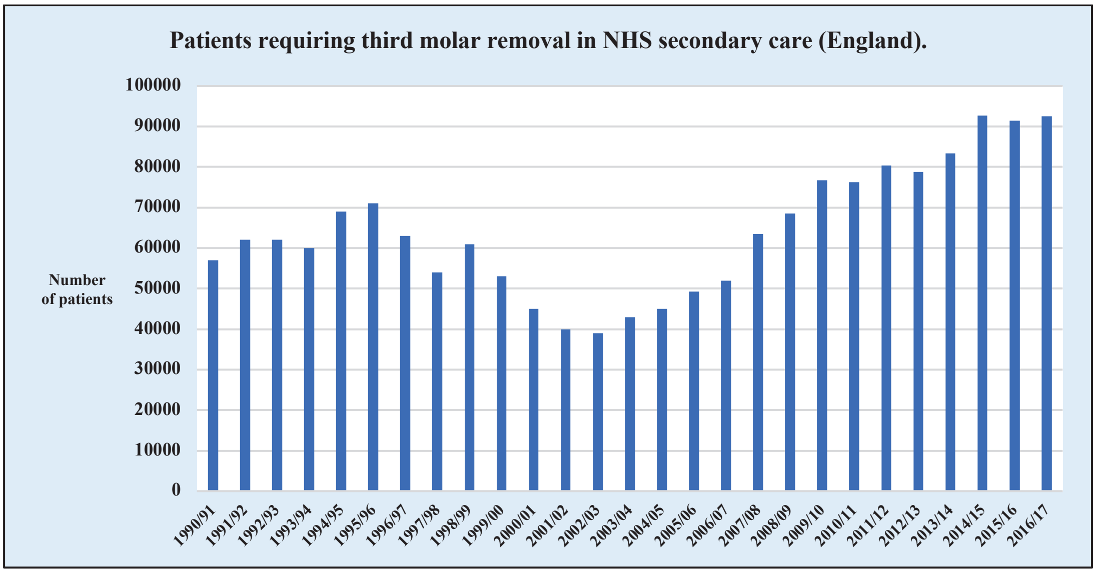
2.3 Results.

HES finished consultant episodes - Data recorded by HES relates to the number of patients who have been admitted to hospital for either a day-case or in-patient procedure under either general anaesthesia (GA). Patients having treatment carried out under conscious sedation and local anaesthesia on an out-patient basis have been known to be recorded as either day-case or as an out-patient procedure. In general, patients who have had third molars removed under local anaesthesia on an out-patient basis do not get included in HES data as this activity is generally recorded as an anonymous out-patient appointment and not as out-patient surgical activity as with other surgical specialties. Out-patient surgical activity may encompass treatment undertaken solely under local anaesthesia but may also include treatment undertaken with conscious sedation and local anaesthesia. Since 2003/4 outpatient activity appears to have been individually recorded but it is unclear whether this relates to treatment under taken under conscious sedation and local anaesthesia or local anaesthesia alone. The true level of out-patient third molar removal is unknown as the vast majority of out-patient local anaesthetic procedures are not recorded as surgical activity. Activity therefore may be significantly underestimated.

From the HES data, approximately 60k people per annum in England had third molar teeth removed in the early period of the 90's (Figure 2.2) (HES, 2018). This number rose to 70k by the mid 90's and averaged approximately 60k patients per year for the whole of that decade. In the first half of the 00's patient numbers started to decline significantly and by 2003 HES data suggests that just less than 40k patients (39,000 patients) per annum where having third molar treatment undertaken in hospital setting as either in-patient or day-case procedures: a reduction on the 1990's average of over 30% (HES, 2018).

From the mid 00's onwards the recording of a small amount of out-patient activity is included in HES data along with inpatient and day-case data and over the latter 5 years of the 00's the number of patients having third molars removed had increased to almost 77k patients per annum in 2009/10 (≈65k in-patient/day-case and 12k outpatient). This equates to an increase of approximately 67% of in-patient and day-case activity recorded in the secondary care sector but a 97% increase in all recorded patient activity compared with the lowest recorded activity of 2002/3. By 2009/10 patients having third molars removed in a hospital setting was most notably at its highest level for 20 years (HES, 2018). Since 2010 the numbers of patients having third molars removed has continued to rise and has reached levels beyond those of the 90s and for 2014/15, 2015/16 and 2016/17 have averaged over 90k patient treatment episodes per annum (Figure 2.2) (HES, 2018). An increase of approximately 50% per annum compared with the average over the 1990's decade.

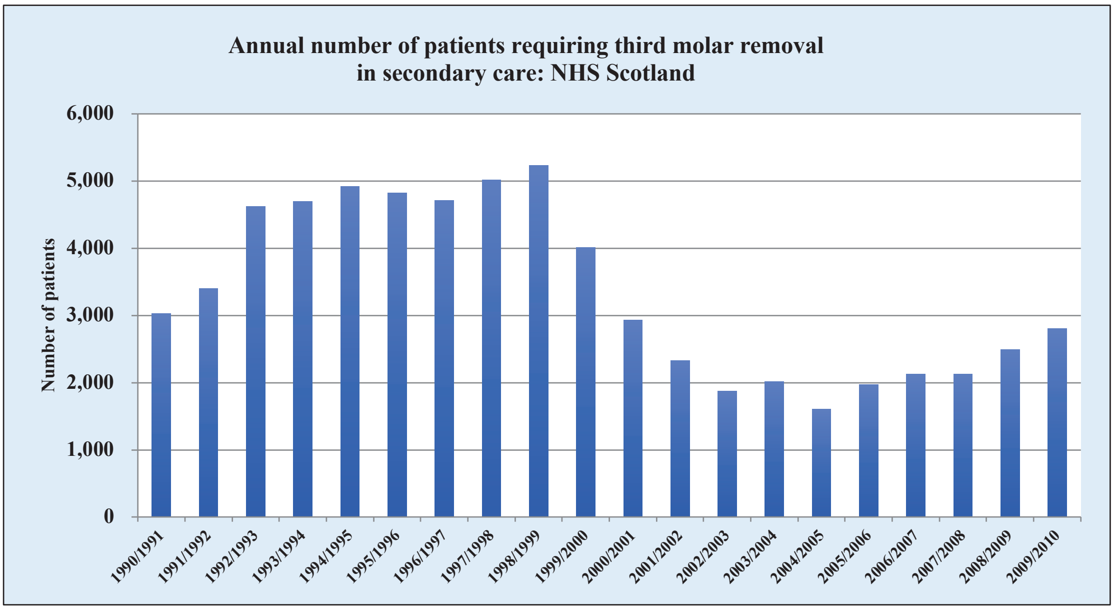
Figure 2.2 Annual number of patients requiring third molar removal in secondary care: NHS England 1990/91 – 2016/17.



***Legend:** This graph illustrates the total annual number of patients recorded as having third molar teeth removed in secondary care within the NHS in England from 1990/91 until 2016/17. For 1990/91 the total number of patients recorded was 57,000. The average annual number of patients having third molars removed during the 1990s was in the region of 60,000 per annum. For the first 3 years of the 00's this figure declined by approximately 30% to a low of 39,000 patients in 2002/3. From 2003/4, this figure increased on a year-by-year basis with the total number of patients having third molars removed by 2016/17 reaching 92,500 – an increase of approximately 135%.*

In Scotland, figures for in-patient/day-case activity follow a similar trend for England (Figure 2.3) (NHS Scotland, 2012). For most of the 90's just under 5,000 cases of third molar removal were undertaken per annum. Subsequent to the introduction of the SIGN guidelines a similar trend in the number of cases per annum is noted, dropping to approximately 1,600 cases per annum by 2005: a reduction of approximately 70%. Post 2005, however a steady year-by-year increase is noted and by 2009/10 the number of patients had increased to approximately 2,800 cases: an increase of 75% from the low of 2004/5, although still 50% less than the average from the 1990s (NHS Scotland, 2012).

Figure 2.3 Annual number of patients requiring third molar removal in secondary care: NHS Scotland.



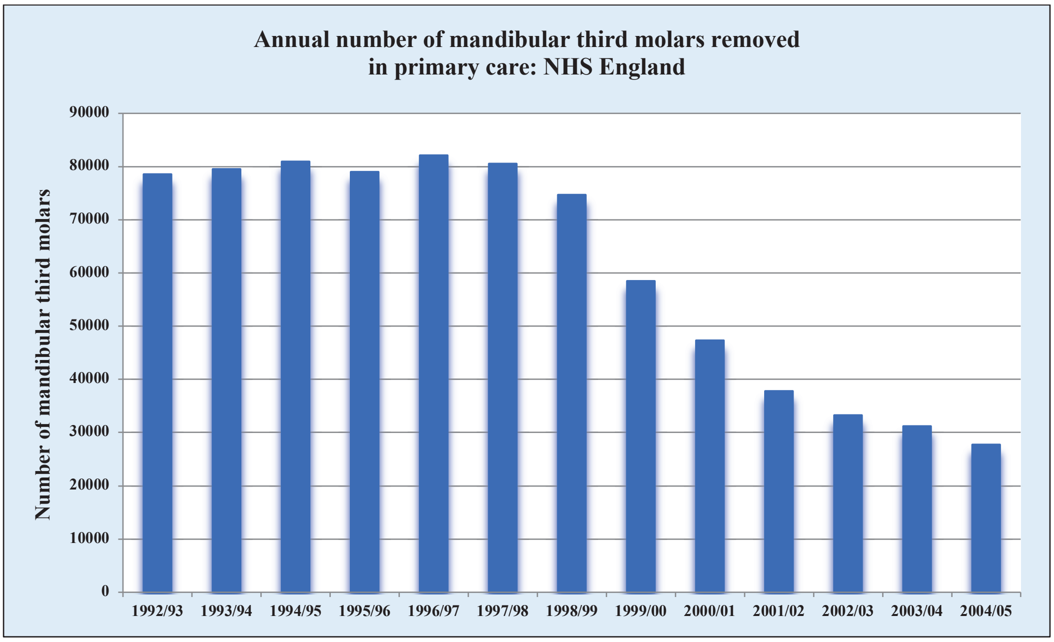
Legend: *This graph illustrates the total annual number of patients recorded as having third molar teeth removed in secondary care within the NHS in Scotland from 1990/91 to 2009/10. For 1990/91 the total number of patients recorded was 3,031. The average annual number of patients having third molars removed during the 1990s was in the region of 4,600 per annum. For the first 5 years of the 00's this figure declined by approximately 70% to a low of 1,606 patients in 2004/5. From 2004/5, this figure increased on a year-by-year basis with the total number of patients having third molars removed by 2009/10 reaching in excess of 2,807. Whilst this trend is increasing this is still approximately 50% less than the 1990's average (McArdle and Renton, 2012).*

2.4. NHSBSA/DPB 2204/2205 codes.

The NHSBSA/DPB records items of treatment of each patient rather than treatment episodes for patients (NHSBSA, 2006). The Statement of Dental Remuneration (SDR) document provides the item of service codes used previously under the old GDS Contract (NHSBSA, 2005). SDR Codes 2204 and 2005 are third molar specific and although third molars would have undoubtedly been removed under other codes such as 2101 and 2201, these codes are not tooth specific and cannot be used to identify third molar activity. In addition, SDR codes 2204/5 can identify both mandibular and maxillary teeth separately. This data set is limited to exclusively mandibular third molars (Md3M) as the combined total of both maxillary and mandibular third molars removed may not accurately reflect the actual number of patients having third molar surgery. By restricting our data set to exclusively Md3M we get a less distorted picture on the actual number of patients. In addition, Md3M tend to cause greater clinical problems, are more surgically complex and have greater post-operative morbidity making them the focus for most published research.

For the period of 1992–2005 in England GDS, the trend in third molar activity follows a comparatively similar pattern to secondary care (Figure 2.4). For most of the 90's approximately 80k Md3M were being removed per annum. Subsequent to 2000 the numbers of Md3M removed declines steadily by over 60% reaching a level of 28k per annum for 2004/5. Data for after this period is not available, as the NHSBSA does not now record it.

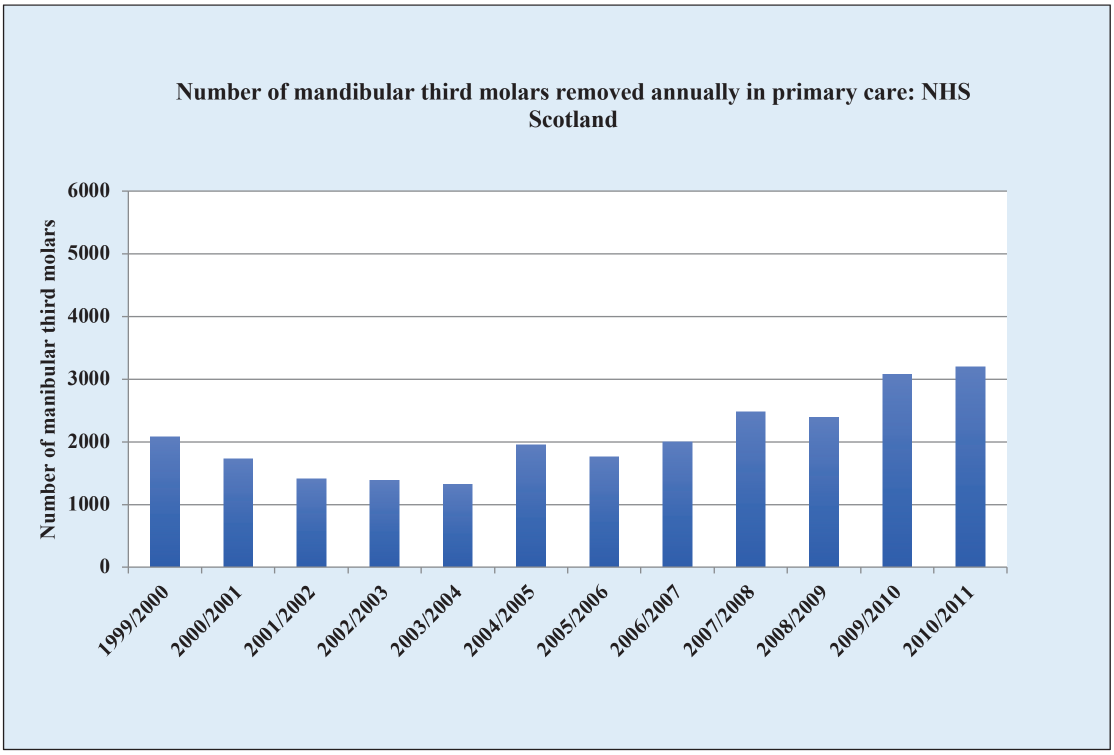
Figure 2.4 Annual number of mandibular third molars (Md3M) removed in primary care: NHS England 1992/93 – 2004/05.



Legend: *This graph illustrates the total annual number of patients recorded as having mandibular third molar (Md3M) teeth removed in primary care within the NHS in England. For 1992/3 the total number of Md3M teeth removed was recorded as approximately 78,000. The average annual number of Md3M removed during the 1990s was in the region of 79,000 per annum. During the 00's this figure declined year–by-year to a low of approximately 28,000 Md3M in 2004/5 (a reduction of approximately 60%). From 2004/5, the NHSBSA stopped recording this data (McArdle and Renton, 2012).*

In Scotland, data for third molar activity continues to be collated for general dental practice (Figure 2.5) (NHS Scotland, 2012). In the first half of the 00's decade, there is a 36% reduction in mandibular third molars removed which mirrors the yearly trend of reduction in England. After 2004, however, mandibular third molar removal progressively increases and by the end of the decade is 130% greater than at its lowest level of 2004. This trend cannot be properly compared with the post 2005 trend for general dental practice in England but it does complement the upward trend of secondary care third molar activity seen in both England, and in Scotland which saw an increase of 66% and 75% respectively over the same time period.

Figure 2.5 Annual number of mandibular third molars (M3M) removed in primary care: NHS Scotland.

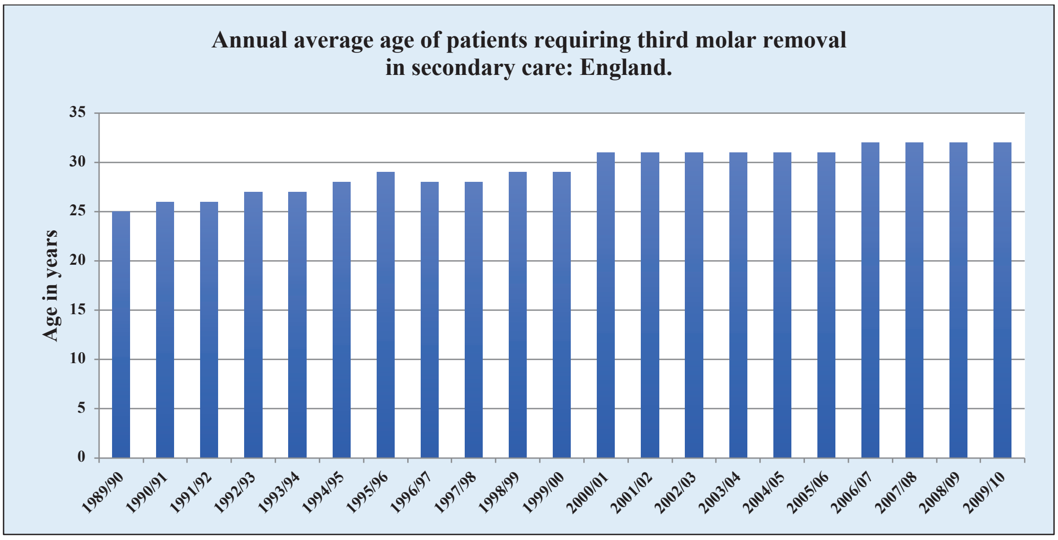


Legend: *This graph illustrates the total annual number of mandibular third molar (Md3M) teeth removed in primary care within the NHS in Scotland for the period 1999/00 through to 2010/11. For 1990/00 the total number of Md3M teeth removed was recorded as 2,078. Over the ensuing four-year period the number of Md3M teeth removed declined to 1,327 by 2003/04 (a reduction of 40%). For the latter half of this decade the number of Md3M teeth removed rose on a year-by-year basis to a total of 3,076 (an increase of approximately 130%) by 2009/10 and 3,196 (an increase of approximately 140%) by 2010/11 (McArdle and Renton, 2012).*

2.5 Age.

HES data reports that the average age of patients requiring third molar removal within the NHS has increased over the last 20 years. In 1990 the average age of a patient having third molars removed as a day-case procedure under general anaesthesia or intravenous sedation was 25 years. This mean age has steadily risen and now the mean age for patients having third molars removed is 32 (Figure 2.6) (HES, 2018) .

Figure 2.6 Annual average age of patients requiring third molar removal in secondary care: England.

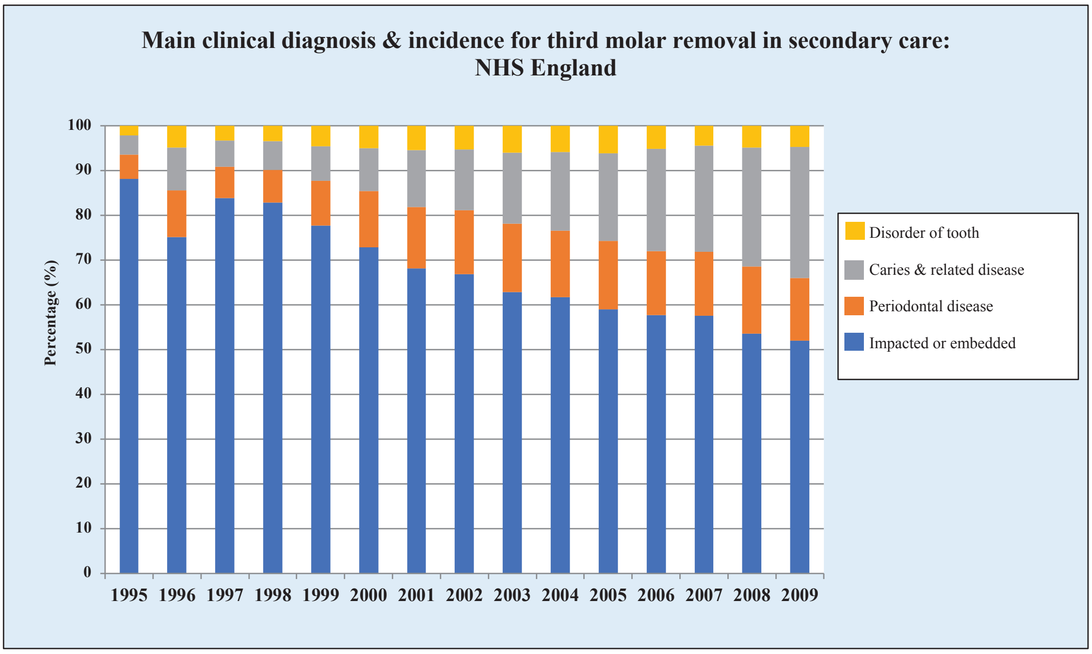


Legend: *This graph illustrates the rise of the average age of patients having third molar teeth removed on a year-by-year basis from 1989/90 through to 2009/10. In 1989/90 the average age of patients having third molar teeth removed was 25 years. This has steadily increased over the ensuing 20-year period and in 2009/10 the average age of patients having third molar teeth removed was 32 years (McArdle and Renton, 2012). (n.b. HES data does not report Standard Deviation or Standard Error statistics to allow incorporation of SD bars within the figure).*

2.6 Clinical indications for third molar removal in secondary care.

HES data also records the main clinical diagnosis for third molar removal (Figure 2.7) (HES, 2018). The most common recorded WHO ICD-10 coding and indication for third molar removal relates to embedded and impacted teeth (K01.0/K01.1) paradoxically these are not a defined NICE indication for third molar removal. For 1995 embedded/impaction is recorded as the main diagnosis for approximately 88% of all third molars removed. Over the next 15 years there is an increase in the proportion of caries or related peri-apical abscess (K02.9/K04.7) being recorded as the main diagnosis from less than 10% in 1995, rising to almost 30% by 2009. In the same period, periodontitis (K05.2/K05.3), as a recorded main diagnosis, increased from a level of approximately 7% in 1997 to 15% in 2009. One notable anomaly of the coding system is that pericoronitis does not have a distinct identifiable ICD code and is coded within the general code for periodontal disease (WHO, 2016).

Figure 2.7 Main clinical diagnosis and annual frequency of disease for third molar removal in secondary care: NHS England.



Legend: *This graph illustrates the recorded main clinical diagnosis/indication, and its annual frequency, for patients having third molar teeth removed in England from 1995 until 2009. In 1995, impacted or embedded third molars accounted for 88%; periodontal disease - 5%, and caries & related infection - 5% of all patients having third molars removed. During this period and up until 2009, the incidence of impacted and embedded teeth had steadily declined from 88% to an incidence level of approximately 50%. For caries & related infection, the incidence has increased from 5% in 1990 to approximately 30% in 2009. The incidence of periodontal disease has increased from 5% to 10% (a 100% increase). The average annual incidence of caries & related infection during the latter 90's was approximately 10% and rose to 30% by 2009: an increase of 200%. (McArdle and Renton, 2012)*

2.7 Discussion

In 2004, a review by Sheldon et al., of the impact that NICE guidance was having over a range of clinical interventions suggested that NICE had no discernible effect on the management of patients with third molar teeth (Sheldon et al., 2004). Data used by this study covered the period from 1995-2001 which observed a downward trend in third molar removal during this time. It was suggested that the downward trend in third molar removal had already began as a consequence of guidance issued by the Royal College of Surgeons of England in 1997 and by the University of York in 1998 (NHS Centre for Reviews and Dissemination, 1998; FDSRCS(Eng), 1997). The sampling period of data was short and only included a single year after the introduction of NICE. HES data prior to 1995, however, suggests that third molar removal was at a similar level for most of the 90's with 1995 being the peak year within that decade (HES, 2018). With the introduction of NICE's guidelines only in 2000, it seems inappropriate to make this conclusion after only one year's worth of post NICE data and a relatively short sample period.

It would appear that a decline in patients having third molars removed did start in the late 90's with the introduction FDSRCS(Eng) guidelines but this data suggests a significant reduction of third molar removal with the introduction of the NICE/SIGN guidelines in 2000 (McArdle and Renton, 2012). It may be that the staggered introduction of the FDSRCS(Eng) guidelines, the University of York's clinical effectiveness document and the NICE/SIGN guidance continued to re-enforce the advice to the dental profession that asymptomatic third molars should not be removed (NHS Centre for Reviews and Dissemination, 1998; FDSRCS(Eng), 1997; SIGN, 2000; NICE, 2000).

In general dental practice the numbers of third molars being removed reduced by over 50% by 2005. For secondary care, data showed a 40% reduction in patients having third molars removed from a peak of 70k in the late '90s down to 40k in the mid '00s. On NICE's premise that 40% of all third molars being removed had no clinical indication for removal, then this data suggests that third molar guidelines were having the desired effect of reducing the number of third molars being removed and therefore reducing healthcare expenditure in this area.

Although data post 2005 is not available for the GDS in England, the data from Scotland and HES would suggest that this dip in primary care third molar activity in England might also be only temporary. Within secondary care in England, the fall in third molar activity mirrors primary care with numbers steadily falling from the late 90's until 2002/3. Following this, however, the numbers for third molar removal in secondary care had begun to rise steadily with an increase from 45k patients per year in 2004/5 to almost 80k patients by 2009/10: an increase of almost 80% in 5 years. By 2016/17 this had risen to 92k patients: an increase of over 100% since 2004/5. Furthermore, the data from NHS Scotland mirrors this increase in third molar activity by 67% in secondary care provision, and by 130% for general dental services for the latter half of the 00's.

The reasons for this increase in third molar activity in the latter half of the 00's and the specific increase in secondary care activity may be explained by three possible hypotheses:

- The possible influence of the new General Dental Services (nGDS) contract in England in 2006.
- A link between the increasing age of patients and the increasing incidence of caries related to third molars.
- Population increase in the UK.

2.8 nGDS

The new General Dental Services (nGDS) contract was introduced in England in March 2006 whereas the GDS contract in Scotland has remained relatively unchanged. Dental treatment was previously provided at a cost per treatment item however the new GDS contract is based on the provision of treatment within treatment bands (NHSBSA, 2005). Consequently, the treatment band generates the fee rather than the service item, or the quantity of different service items. This results in NHS dentists receiving the same fee for a course of treatment that may include just a single restorative procedure but the exact same fee for a course of treatment for multiple restorative procedures, endodontic procedures and extractions. In this example the fee for a band 2 course of treatment may be in the region of £60-£70 and realistically this limited fee for multiple items of treatment does not necessarily cover the actual cost of providing the treatment.

As the contract does not offer remuneration based on the time the dentist spends with the patient, nor for the number nor complexity of treatment items, it has been suggested that dentists are unwilling to undertake some of the more complex treatment items on the NHS and are subsequently referring patients to other providers for treatment (Dispatches C4, 2011). Up until 2015, the new GDS contract allowed GDP's to refer patients for treatment that they themselves did not feel able to provide whilst still claiming payment for the treatment. This may explain why referrals to hospital secondary care providers for Oral Surgery procedures, such as third molar extractions, had dramatically increased. Oral surgery referrals to Guy's and St Thomas's NHS Foundation Trust in London had observed a 100% increase between 2004/5 and 2009/10 (McArdle, 2010). These observations may only be partly attributable to the increase in third molar removal in secondary care, as the trend in secondary care third molar removal had already started to rise prior to the introduction of the new contract. From the trough of 2003 through to 2005, the year before the new contract was introduced in England, third molar activity was already on the increase HES, 2018). In Scotland, this upward trend in third molar removal post 2005 is mirrored in both primary and secondary care settings suggesting that the upward trend in England may be multi-factorial (NHS Scotland, 2012).

2.9 Dental Caries and Age

In relation to third molars, caries can affect the third molar itself or more significantly occur in the distal cervical area of the second molar tooth due to the mesio-angular impaction of the third molar against it. Caries is a disease that is relatively slow to develop compared with pericoronitis and as a consequence caries develops later in patients by comparison (Bruce et al., 1980; McArdle and Renton, 2006; McArdle et al., 2018). From the HES data a significant increase in the number of patients requiring third molar removal was observed. From 1995 up until 2009 the recorded incidence of caries and its sequalae, as an indication for removal, had increased from approximately 7% to almost 30% of all patients requiring third molar removal, an increase of over 300% (McArdle and Renton, 2012).

It may be that the rapid dip in the number of third molar extractions in the early 00's was due to a rigid interpretation and application of third molar guidelines and as such third molars were actively *not* removed. This may be true in cases of single or mild forms of pericoronitis or solely the presence of a partially erupted and impacted third molar that may have been used as the indication for removal pre-2000.

Third molars are not erupting later in life to account for the increase in mean age from 25 years to 32 years during the last 25 years. Third molars are being retained for longer, either as a result of lack of disease affecting younger patients, or a more palliative approach to the management of third molar disease. Patients may be more inclined to be treated with antibiotics for recurring episodes of pericoronitis and thus avoid, or more likely, delay the removal of the third molar.

The fact that patients are retaining third molars later into life makes them more vulnerable to one of the problematic consequences of the oral environment: dental caries. The likelihood of this will be evident especially if the teeth are impacted, partially erupted and difficult to clean. Older patients with good dental health are more prone to having third molar teeth removed because of caries related indications such as DCC in the second molar (Adeyemo et al., 2008; Bruce et al., 1980; Chang et al., 2009; Chu et al., 2003; McArdle and Renton, 2006; Ozeç et al., 2009; Patel et al., 2017; Toedtling and Yates, 2015). This data confirms that as patients have become older, dental caries has become an ever-increasing problem related to third molars. This group of patients may be contributing to the rebound increase in the number of third molars being removed.

With the mean age of patients increasing from 25 years to 32 years of age, we see an increase in the number of patients requiring third molar removal due to caries. Over the age of 30 years patients are more likely to have third molar teeth removed due to the effects of caries than younger patients (Bruce et al., 1980; Chang et al., 2009; Chu et al., 2003; McArdle and Renton, 2006). Consequently, would it be reasonable to consider that any asymptomatic, partially erupted, impacted third molar, if retained, may ultimately cause patients clinical problems such as caries. If these problems are detrimental to the dental health of the patient, then should we not consider defining the optimum time for removal – either at the time of disease presentation or even prior to the damage that the disease may cause especially if the damage is related to the second molar in the form of distal cervical caries.

2.10 Population increase in the UK

Population growth occurs by two primary means. A net increase in population can be brought about by there being more births than deaths per annum on a year by year basis or by an increase in net migration; ie, immigration being greater than emigration. The birth rate in the UK has been relatively uniform since the mid 1970's with approximately 750k life births per year (ONS, 2016). The number of deaths per annum numbers approximately 600k per year giving a net natural increase in population of approximately 150k per annum. Since 1992 net migration into the UK has increased and since 1998 the net migration has been approximately 200k per annum. Although the number of people in the UK has continued to increase over the last 30 years, the rate of population increase has varied. From 1990 to 2000 the UK population increased by 2.8% in total, with an annual growth rate of 0.28%. From 2000 to 2010 the total increase was 6.5%, with an annual growth rate of 0.64%, and for the period of 2010 to 2020 the projected increase in population will be 7.3%, with an annual growth rate of 0.71% (ONS, 2016).

The continued increase in population will undeniably contribute to an increase in the number of patients requiring third molar teeth removal, however the rate of population change during the last 20 years does not reflect the rate of increase of patients having third molar surgery undertaken. Based solely on HES data, the number of patients having third molar surgery had increased by 27% in the 10 years from 2000 to 2010 from the 1990's average of 60k patients. Although there was a fall in the number of patients having third molars removed in the late 90's and early 00's the rate of increase from 2003 to 2010 was approximately 10% per annum. In the 5 years from 2010 to 2014/15 the total increase was 20%, with an average annual rate of increase of 4%. Since 2014 until 2017 the number of patients has remained fairly constant at approximately 92k patients per year.

The increase in the number of patients having third molars removed cannot solely be accounted for by an increase in the population, as the increase in the annual rate of the number of patients having third molars removed is significantly greater than the annual rate of increase of the population in the UK as a whole.

2.11 ICD-10 Coding

There appears to be a lack of specificity in coding as it relates to studies such as this, which leads to problems in interpretation. Caries as a diagnosis is non-specific for coding purposes for third molar studies. Caries associated with the third molar is an indication for third molar removal but distal cervical caries on the second molar in the presence of a mesio-angular or horizontally impacted third molar is also an indication for third molar removal. Both of these clinical conditions appear to be on the rise in older age groups (Bruce et al., 1980; Chang et al., 2009; Chu et al., 2003; McArdle and Renton, 2006; McArdle et al., 2019). The ICD coding system does not allow us to separately classify the location of caries between the third molar and the second molar and as a consequence this limits the ability to interpret data accordingly. However, the frequency of caries related to third molars has increased with age and its consequences have to be managed.

Pericoronitis is a definable clinical problem that affects partially erupted teeth and accounts for the removal of up to 60% of all mandibular third molar teeth (Brickley et al., 1996; Knutsson et al., 1996; Lysell et al., 1988; Nordenram et al., 1987; van der Linden et al., 1995). Pericoronitis is not, however, recognised by the WHO-ICDN coding system as a unique diagnosis and is categorised in an un-coded sub-category for periodontal disease (ICD codes K05.2 and K05.3) (WHO, 2016). If databases are recording ICD-10 codes of K05.2 or K05.3, do they mean periodontal disease or pericoronitis? This flaw creates serious problems in accurate data interpretation. Local periodontal disease affecting the second molar tooth, in addition to periodontal disease of the third molar itself, are distinct indications for third molar removal, but to classify both pericoronitis and periodontal disease together is inappropriate and makes data interpretation difficult.

Impaction and embedded teeth are not in isolation an indication for third molar removal but merely an observation of the ectopic position that develops for the tooth. A tooth's abnormal position is a developmental anomaly and along with other developmental anomalies is defined within the ICD10 coding system (WHO, 2016). This developmental anomaly ultimately accounts for the secondary disease processes that can affect impacted third molar teeth but recording the developmental anomaly rather than the disease that it predisposes to creates an imbalanced observation of the indications for third molar removal. In view of the actual HES incidence of impaction being comparable with the reported incidence of pericoronitis, it could be presumed that impaction is being recorded instead of pericoronitis (Brickley, et al., 1996; HES 2018; Lysell et a, 1988; Nordenram et al., 1987; Ozeç et al 2009; Phillips et al., 2007; van der Linden et al., 1995).

Accurate data collection in third molar studies and clinical coding systems is essential if data is to have any meaningful value. If the WHO ICD system is to be used for third molar data collection, then it will require an overhaul to be fit for this purpose and to appropriately reflect the actual disease processes that afflict third molars.

2.12 Conclusion

With the introduction of clinical guidelines, a decline in patients having third molars removed occurred. This trend, however, has now been reversed and steadily increased to and beyond pre-NICE levels. The initial financial savings that the NHS would have incurred have been short-term and with more patients attending secondary care for third molar procedures, costs are now greater than prior to the introduction of NICE. Patients are becoming older and more patients are experiencing caries as an indication for third molar removal even though the dental and oral health of the population continues to improve (ADHS, 2000; ADHS, 2011). Indeed patients with mandibular third molars who succumb to distal cervical caries on their second molar teeth have on average better dental health than their peers (McArdle and Renton, 2006).

It has been appreciated for some time that as the dental health of the population has improved the early loss of first molar teeth in children and adolescents does not occur as frequently as before (Thomas et al., 1994). Early loss of the first molar results in the forward drift and/or tipping of the second molar creating space distally for the third molar to erupt unhindered and thus reduces the likelihood of impaction. Conversely, retention of the first molar restricts this space in the retro-molar area and no doubt contributes to the likelihood of impaction of the third molar tooth (Thomas et al., 1994). The increase in third molar surgery seen over the last 30-40 years may not be due to inappropriate over-prescribing or prophylactic third molar removal but may, in fact, be due to the paradoxical consequence of improved dental health. It is likely that the number of patients requiring third molar removal will always be substantial.

Chapter 3.

Diseases associated with mandibular third molar teeth.

Aspects of this chapter were published as:

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3.1 Introduction.

As discussed in chapter 1, the eruption process for mandibular third molar teeth (Md3M) can result in two distinct end-points. Where present, many can erupt into a functional and natural non-impacted position, however many Md3M fail to erupt appropriately into a functional position and become impacted, either in a partially erupted state or a non-erupted and embedded state. Both impacted and non-impacted Md3M teeth can succumb to, or contribute to, a variety of dental related diseases that can indicate the removal of the mandibular third molar tooth (AAOMS, 2016; FDSRCS(Eng), 1997; SIGN, 2000; NICE, 2000). Common Md3M diseases include pericoronitis; dental caries; caries related disease such as peri-apical infection; odontogenic cyst formation and periodontal disease. Md3M can contribute to and be a causative factor in the development of disease associated with the mandibular second molar teeth (Md2M) such as distal cervical caries (DCC) or periodontal disease (Allen et al., 2009; Blakey GH et al., 2006; Blakey et al., 2002; Chang et al., 2009; Elter et al., 2004; Elter et al., 2005; Falci et al., 2012; McArdle and Renton, 2006; McArdle et al., 2014; Oderinu et al., 2012; Ozeç et al., 2009; Toedtling et al., 2016; White et al., 2006). In addition, Md3M may also be removed to facilitate other forms of dental treatment such as orthodontics and orthognathic surgery (AAOMS, 2013; FDRCS(Eng), 1997).

There have been many papers written on the nature and spectrum of diseases related to third molar teeth, both lowers and uppers, however as has been outlined in chapter 2, the effect and impact that NICE has had on the nature and the spectrum of disease has been significant. With the mean age of patients rising from 28 to 32 years of age, since 2000, there has been a concomitant increase in the incidence of dental caries related disease as the primary indication for the removal of third molar teeth (HES, 2018; McArdle et al., 2018; McArdle and Renton, 2012)

The diagnostic statistics obtained from HES do not reflect the impact that NICE has had, as this data was based on WHO ICD-10 codes (WHO, 2016). These ICD-10 diagnostic codes can be misinterpreted in a number of ways as multiple codes exist for the variations of dental caries and periodontal disease. Dental caries for example has a single principal code of K02 but has 6 specific subcategory codes, such as K02.0 for enamel caries, K02.1 for dentine caries, K02.9 for unspecified caries and others.

Likewise, periodontal disease has a single principle code of K05 and K06 subcategory codes, such as K05.2 for acute periodontitis, K05.3 for chronic periodontitis, etc. ICD-10 codes also have 9 separate codes for diseases of the dental pulp, however most pulpal disease is a consequence of dental caries. The most common indication for the removal of impacted third molars is pericoronitis, however acute and chronic pericoronitis are in an un-coded sub-category for periodontitis: K05.2 and K05.3. From a dental perspective and clinical definition, pericoronitis and periodontitis are two separate and unrelated clinic diagnoses and why they have been categorised together as such is incomprehensible. Pericoronitis does not have an individual code and in essence does not exist as a specific and identifiable disease or diagnosis. HES data does code third molar teeth as impacted and embedded teeth as a defined diagnosis (K01.0 and K01.1) and with this coding represents approximately 50% of all third molar coding, there is a suspicion that codes K01.0 and K01.1 are being used to identify pericoronitis (McArdle and Renton, 2012). Moreover, impacted and embedded teeth are not a NICE defined indication for third molar removal. The combined consequences of these coding anomalies result in failure to accurately define the true spectrum of disease related to impacted third molars. HES data, based on ICD-10 codes, gives us an incomplete representation of diagnostic data and consequently the true spectrum and incidence of disease is presumptive, due to the ICD-10 coding limitations.

The aim of this chapter was to more clearly define the nature and spectrum of disease that indicates Md3M removal in a representative group of patients who attended for removal from both primary and secondary care and who were treated as outpatients under local anaesthesia or as day-case patients under conscious sedation or general anaesthesia.

This chapter presents the results from a prospective cohort of 1011 patients attending for Md3M removal. The aims of the chapter were to determine the primary clinical indication for Md3M removal and to ascertain the variation and spectrum of disease based on the nature of impaction of the Md3M tooth. Both impacted Md3M and functional non-impacted Md3M were included in the study group cohort.

3.1.1 Aims

The primary aim of the chapter was to determine the clinical diagnoses for patients undergoing Md3M removal from a cohort of 1011 patients. Patients were assessed and grouped into 5 year age cohorts to determine if there was any age-related variation in disease. In addition, patients' Md3M were assessed in relation to the eruption and angulation status of impaction of the Md3M to determine if angulation and age of patients influenced clinical diagnoses.

3.1.2 Ethics

The local ethics committee of KCL Dental Institute was approached for advice regarding the need for ethical approval and as data collection would neither identify individual patients nor influence treatment or outcomes, formal ethical approval was not required.

3.1.3 Methodology

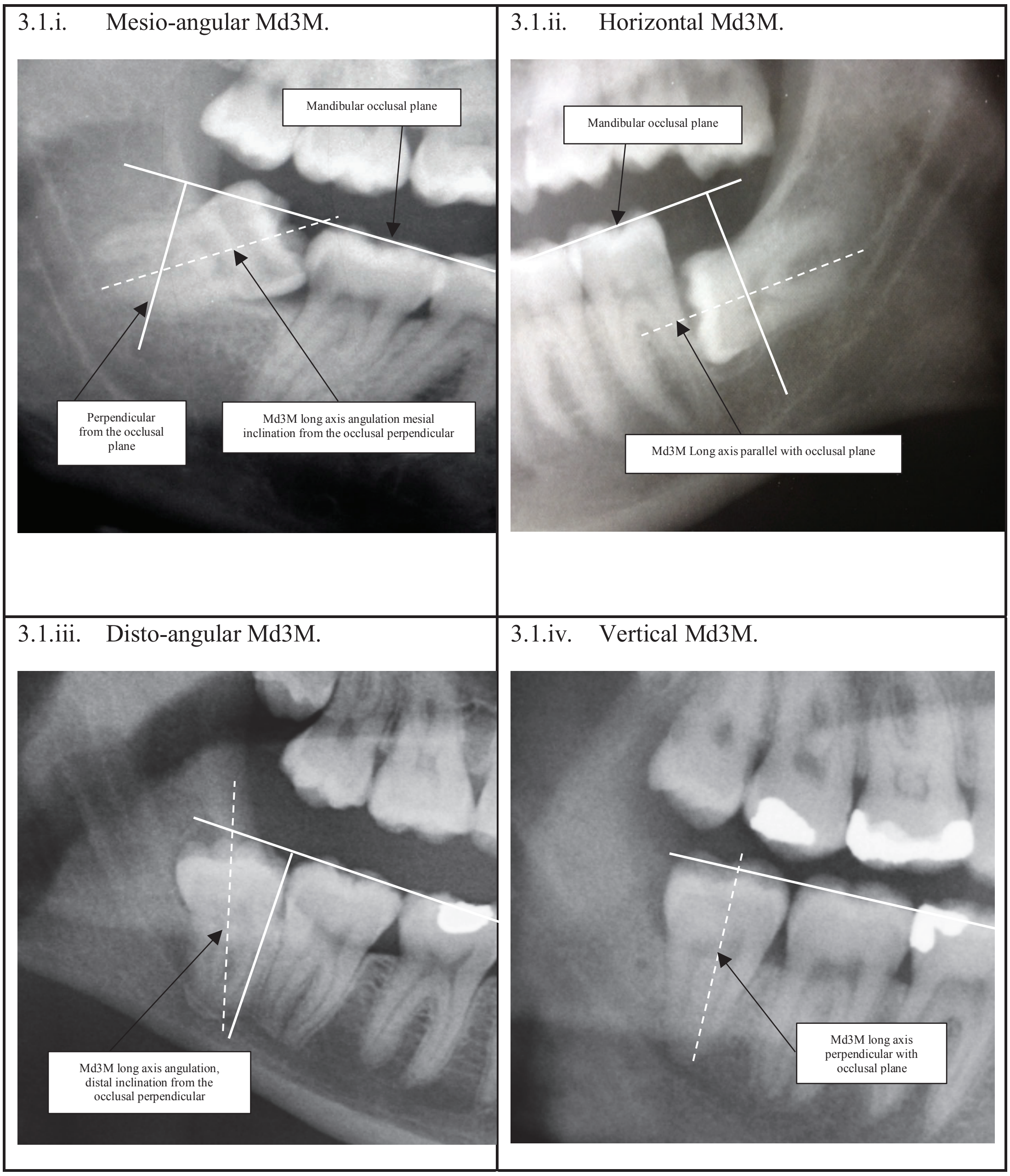
Data from 1011 consecutive patients attending for Md3M assessment and removal was collated longitudinally over a 2-year period (2013-15) and then retrospectively analysed. In the secondary care setting, all patients were selected and included for data collection from those randomly allocated to consultant clinics and treatment sessions under direct consultant care of the author. In primary care (NHS and private provision), all patients referred and treated by the author for removal of third molars were included. Patients were selected on a continuous basis with all patients requiring third molar removal being included.

Patients were evaluated and the variables were recorded on a third molar patient proforma (see appendix I). Data recorded included: patient identifier; patient gender as recorded on clinical notes; age of patient at presentation; Decayed Missing Filled Teeth (DMFT) score; charting presence/absence of specific third molar (FDI notation 18, 28, 38 ,48); eruption status of third molar (erupted, partially erupted, unerupted); angulation of third molar by standard convention (vertical, mesio-angular, horizontal, disto-angular or ectopic); whether removal of the third molar was indicated or not, and the clinical diagnosis for each individual third molar indicated for removal. Data was transferred onto an Excel master database; anonymised to eliminate patient identifiers, and analysed using IBM SPSS Statistics for Windows (version 23.0 (IBM Corp)) and online statistical software MedCalc. In total, 1011 patients who had 1431 mandibular third molar removed were assessed.

The eruption status was defined as either unerupted, partially erupted, erupted or over-erupted. Any tooth that was detectable either visually or clinically with a periodontal probe was deemed exposed to the oral environment and consequently defined as partially erupted. Teeth with a visible occlusal surface but with high distal gingival collar were also deemed partially erupted. Teeth that could not be clinically detected visually and could not be detected with a periodontal probe were deemed unerupted. Md3M, which were defined as erupted, had a complete gingival collar below the level of the maximum bulbosity of the crown and sitting in a vertical functional position on the level of the occlusal plane.

The angulation of the Md3M was defined and categorised by recognised convention as either vertical, mesio-angular, disto-angular, horizontal, or ectopic (ectopic was defined as all other possible angles of impaction distinct of the other four; for example, inverted). Angulation of the Md3M was determined by the tooth's vertical, long axial relationship with the perpendicular of the occlusal plane of the mandibular teeth (Figure 3.1). Mesio-angulation was defined as the mesial, or forward, angulation of the Md3M, from the occlusal perpendicular; in effect, where the mesial tilt of the Md3M was greater than zero degrees and less than 90 degrees (Figure 3.1.i). Where the long axis of the Md3M was parallel with the mandibular occlusal plane the angle was defined as horizontal (Figure 3.1.ii). Disto-angulation was defined as the distal angulation of the Md3M from the perpendicular of the mandibular occlusal plane was minus zero degrees and less than -90 degrees (Figure 3.1.iii). Where the long axis of the Md3M was perpendicular to the mandibular occlusal plane the angulation was defined as vertical (Figure 3.1.iv).

Figure 3.1 Calculating the angulation of impaction of the Md3M.



Legend: *This figure demonstrates the standard conventional definition of the angulation of impacted mandibular third molar teeth.*

The precise calculation of the Md3M angulation was not critical as this was defined solely in terms of this standard convention. The angulation of the Md3M was determined therefore by simple clinical and radiographic observation. Intra-rater and inter-rater reliability for assessing angulation of the third molar was assessed using Cohen's Kappa co-efficient. Twenty patients chosen at random who had 38 Md3M removed were assessed to determine intra-rater and inter-rater reliability of assessing the angle of impaction. Intra-rater reliability was assessed at the end of data input with a time period of over one year between initial angulation assessment and re-assessment. Inter-rater assessment was carried by a second oral surgery consultant at the same time. Calculation of Cohen's Kappa co-efficient followed standard calculation and interpretation as defined by Landis and Koch (Landis and Koch, 1977).

For intra-rater reliability of angulation assessment the Kappa co-efficient was 0.67 (SE 0.095, 95% CI 0.48-0.85) demonstrating substantial intra-rater agreement. The Kappa co-efficient computation for inter-rater reliability of angulation calculated that the Kappa co-efficient was 0.6 (SE 0.1, 95% CI 0.41-0.80) demonstrating moderate to substantial inter-rater agreement.

The ***primary*** diagnosis and clinical indication for Md3M removal was recorded but was not circumscribed nor limited to any specific clinical guidance or protocols for third molar removal such as NICE or NIH guidance (NICE, 2000: NIH, 1980). This was to permit any possible clinical diagnoses to be recorded. Patients requiring Md3M removal due to pulpitis, dental abscess, peri-apical periodontitis, etc; where caries of the Md3M tooth was the promoter lesion for the development of these consequent diseases, were defined and recorded collectively as 'caries and related disease' (C&RD), as these diagnoses represent specific stages of the progression of dental caries. All subgroups of pericoronitis, such as acute, chronic, sub-acute and recurrent pericoronitis were grouped collectively into a single diagnosis of pericoronitis.

All patients attended either a primary care based specialist oral surgery clinic, or a secondary care oral surgery department of Guy's and St Thomas's NHS Foundation Trust Hospital. Treatment was carried out with either local anaesthesia; local anaesthesia and sedation, or day-case general anaesthesia.

In relation to study bias; patients from both primary care and secondary care theoretically reduce bias as treatment includes patients from both primary and secondary clinical care provision and all levels of clinical complexity and anaesthesia modalities. In relation to overall prevalence of third molar disease, bias is compounded as only patients who have disease and are having their third molar removed were included and, therefore, did not include patients who may have asymptomatic and undiagnosed disease but had not been referred for assessment and treatment.

3.1.4 Statistical analysis.

The original sample size was calculated by power calculator (G*Power 3.1.5) allowing for a confidence level of 95% with a 5% margin of error (standard power level of 80% and alpha level of p=0.05). Patient age and the angulation of the mandibular third molar tooth were defined as the primary independent variables, whilst disease of the mandibular third molar was defined as the primary dependent variable. Sample size calculation was determined at 969 however a total of 1011 patients were ultimately assessed.

Sample and outcome characteristics were summarised using descriptive statistics. Sample means, number, range and standard deviation were calculated for patient age related to Md3M angulation and Md3M disease diagnoses. Angulation related frequency and distribution of disease was also calculated. The comparison of Md3M subgroups for the disease variation and the Md3M angulations of impaction were carried out using Z test for proportions. The mean age of patients for different disease presentation and with impaction status were compared using one way ANOVA. Statistical significance was assumed at 5% level and all the analyses were carried out using SPSS version 23.0.

3.2 Results

Of the 1011 patients who were assessed, 604 (60%) were female and 407 (40%) male. In total, 591 patients had one Md3M removed and 420 patients had bilateral Md3M removed: a total of 1431 Md3M were removed. The number of Md3M present with no clinical indication for removal was 376, and 215 Md3M were clinically absent. The mean age of patients having Md3Ms removed was 32.4 years, (SD 11.5 years, range 12-87 years).

3.2.1 Md3M characteristics and disease

The overall distribution of disease that indicated Md3M removal is shown in Figure 3.2. Pericoronitis was the most common indication recorded accounting for 49% of all Md3M removed. Caries & related disease (C&RD) for 27% of Md3M removed; Md2M DCC for 14%; periodontal disease for 5%, and dental/odontogenic cyst for 2%. Collectively, the remaining 10 recorded diagnoses accounted for 4% of all diagnoses, and individually accounted for less than 1%. Caries combined, i.e. C&RD and Md2M DCC, as an overall indication for removal of Md3M, accounted for the removal of 41% of all Md3M.

Figure 3.2 Primary diagnosis and distribution of all Md3M requiring removal.

Diagnosis for removal	**Number of Md3M removed**	**Percentage (%)**
1 – Pericoronitis	698	49%
2 – Caries & related disease (C&RD)	382	27%
3 – Md2M DCC	198	14%
4 – Periodontal disease	63	5%
5 – Dentigerous/odontogenic cyst	33	2%
6 – Prevention of Md2M	18	1%
7 – Pre-orthognathic surgery	12	0.8%
8 – Food trap	9	0.6%
9 – External resorption of Md2M	4	0.3%
10 – Prophylactic secondary to GA	4	0.3%
11 – Fractured tooth (not caries)	3	0.2%
12 – Pre-orthodontic	2	0.2%
13 – Pre-radiotherapy	2	0.2%
14 – Ramus bone graft – pre-implant	1	0.1%
15 – Internal resorption	1	0.1%
16 – Non-function	1	0.1%
Total number of Md3M (1011 patients)	**1431**	**100%**

Legend: *This table illustrates the clinical diagnosis of 1431 Md3M removed from 1011 patients along with the total number and percentage distribution of 1431 Md3M removed. In total, 591 patients had one Md3M removed and 420 patients had bilateral Md3M removed. (McArdle et al., 2018)*

Of the 1431 Md3M removed, a total of 82% Md3M were impacted and 18% were vertical, non-impacted and in a functional position. Mesio-angular impacted Md3M (MAMd3M) accounted for 29% of the total removed, with horizontal Md3M (HORIZMd3M) impactions accounting for 14%; disto-angular Md3M impactions (DAMd3M) for 15%, and ectopic impactions for less than 1%. Vertically *impacted* Md3M (VERT(imp)Md3M) accounted for 24% and 18% Md3M were vertical and *non-impacted* (VERT(non)Md3M). (Figure 3.3).

Figure 3.3 Primary diagnoses and distribution of Md3M requiring removal based on angulation and impaction.

Primary diagnosis for Md3M removal	VERTMd3M impaction	DAMd3M impaction	HORIZMd3M impaction	MAMd3M impaction	ECTOPICMd3M impaction	VERTMd3M non imp
N=1431	N=348 (24%)	N=210 (15%)	N=198 (14%)	N=413 (29%)	N=11 (<1%)	N=251 (18%)
Pericoronitis	271 (78%)	176 (84%)	106 (53%)	131 (32%)	6 (54%)	8 (3%)
C&RD	56 (16%)	26 (12%)	22 (11%)	62 (15%)	Nil	213 (85%)
Md2M DCC	Nil	Nil	18 (9%)	180 (44%)	Nil	Nil
Periodontal disease	2 (<1%)	3 (1.5%)	25 (13%)	13 (3%)	Nil	22 (9%)
Dentigerous/odontogenic cyst	4(1%)	4 (2%)	16 (8%)	5 (1%)	4 (36%)	Nil
Prevention DCC 2nd molar	Nil	Nil	3 (1%)	14 (3%)	Nil	Nil
Pre-orthodontic orthognathic surgery	Nil	Nil	4 (2%)	6 (1%)	Nil	Nil
All other indications total	15 (<5%)	1(<1%)	4(2%)	2(<1%)	1(9%)	8(<4%)

Legend: *This table illustrates the clinical diagnoses of 1431 Md3M removed from 1011 patients based on angulation and impaction. Pericoronitis is the main indication for all types of impacted Md3M apart from mesio-angular impaction where Md2M DCC was the primary indicator. Md2M DCC was only observed related to MAMd3M and to HORIZMd3M. The incidence of C&RD was similar in all types of impaction. (McArdle et al., 2018)*

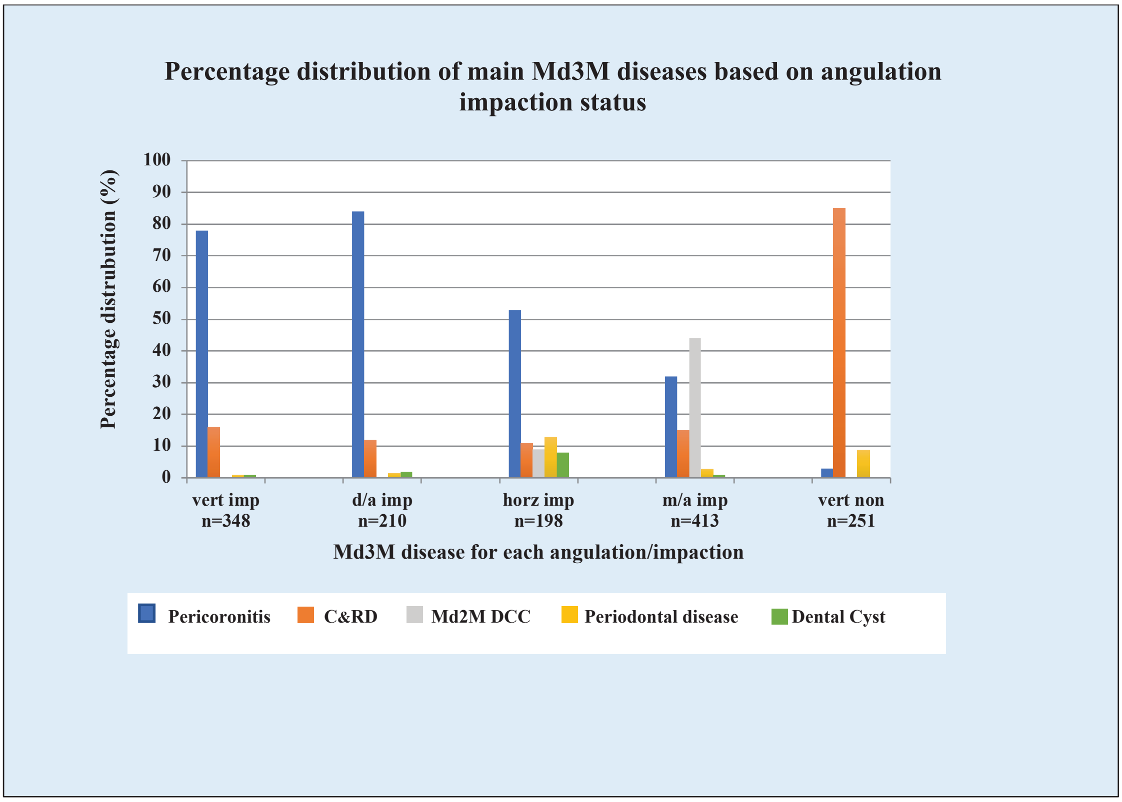
If non-impacted Md3M are isolated from and compared with impacted Md3M then the distribution of disease can be considered comparatively. Pericoronitis accounted for the removal of 58% of impacted Md3M compared with 3% of non-impacted Md3M ($p<0.0001$), C&RD for 14% of impacted teeth compared with 84% of non-impacted teeth ($p<0.0001$), Md2M DCC for 17% of impacted teeth and 0% of non-impacted teeth ($p<0.0001$), periodontal disease for 4% of impacted teeth and 9% of non-impacted teeth ($p<0.001$), and finally dental/odontogenic cyst for 3% of impacted teeth compared with 0% non-impacted ($p<0.01$).

The most common eruption status for Md3M requiring removal was that of partial eruption, which totalled 1133 Md3M (79%). Erupted teeth accounted for 251 Md3M removed (18%); unerupted teeth accounted for 43 Md3M (3%), and 4 Md3M were over-erupted (<1%).

3.2.2 Md3M disease diagnoses and angulations

Disease diagnoses in relation to the angulation and impaction of the Md3M was also considered and are presented in figures 3.3 and 3.4.

Figure 3.4 Percentage distribution of the main Md3M disease based on angulation and impaction status.



Legend: *This figure illustrates the percentage distribution of the main principal diagnoses of Md3M removed based on angulation and impaction. Pericoronitis is the main indication for all types of impacted Md3M apart from mesio-angular impaction where Md2M DCC was the primary indicator. Md2M DCC was only observed related to MAMd3M and to HORIZMd3M. The incidence of C&RD was similar in all types of impaction. (McArdle et al., 2018)*

Of the most common diseases, pericoronitis accounted for the removal of 32% of all MAMd3M compared with 84% of all DAMd3M ($p<0.001$); 78% of all VERT(imp)MD3M impactions ($p<0.001$); 53% of all HORIZMd3M ($p<0.001$) and 3% of vertical non-impacted teeth (VERT(non)Md3M) ($p<0.001$).

In contrast C&RD accounted for the removal of 15% of MAMd3M compared with 12% of DAMd3M ($p=0.4$), 16% of all VERT(imp)Md3M ($p=0.7$), 11% of HORIZMd3M ($p=0.2$), but 85% of VERT(non)Md3M (p<0.001). DCC of the Md2M accounted for the removal of 44% of all MAMd3M and 9% of HORIZMd3M (P<0.001) but was not recorded in any of the other groups (P<0.001).

Periodontal disease accounted for the removal of 13% of all HORIZMd3M compared with 3% of MAMd3M (P<0.001); 1.5% of DAMd3M (P<0.001); 9% of VERT(non)Md3M (p=0.18) and less than 1% of VERT(imp)Md3M (P<0.001).

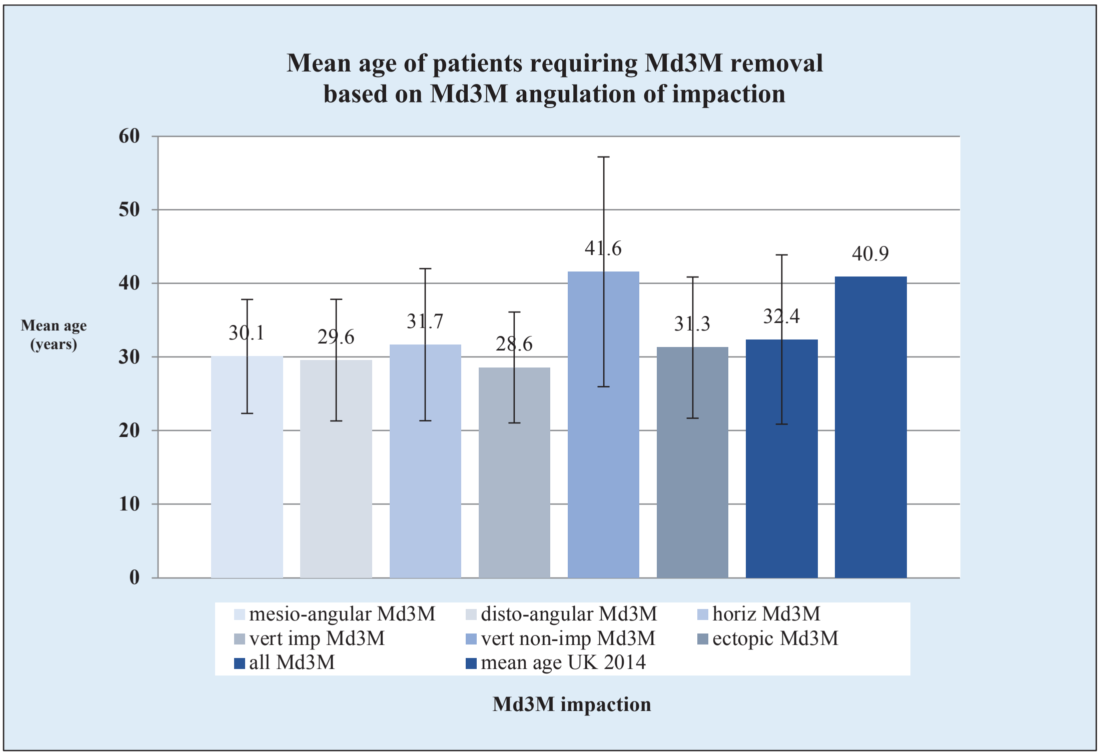
The variation of disease seen in the differing types of impaction suggests that certain diseases, such as Md2M DCC, occur dependent upon the angulation of impaction and other disease, such as C&RD, independent of the angulation.

3.2.3. Mean age, impaction status & disease.

The mean age of all patients having Md3Ms removed was 32.4 years (range 12-87 years, SD: 11.5 years). In addition, the mean age of patients, based on the angulation of impaction of the Md3M was calculated (Figure 3.5) and the mean age of patients based on the most common diagnoses (Figure 3.6).

For patients having a MAMd3M removed, the mean age of patients was 30.1 years (range 12-67 years, SD: 7.7 years); for DAMd3M impactions, the mean age was 29.6 years (range 19-86 years, SD: 8.3 years); for HORIZMd3M impactions - 31.7 years, (range 14-87 years, SD: 10.3 years); for VERT(imp)Md3M impactions - 28.6 years, (range 16-57 years, SD: 7.5 years); for VERT(non)Md3M 41.6 years, (range 17-83 years, SD: 15.6 years); and for ectopic impactions the mean age was 31.3 years, (range 18-45 years, SD 9.6 years). For reference, the Office for National Statistics in the UK report that the mean age of the UK population is 40.9 years. (ONS, 2014b)

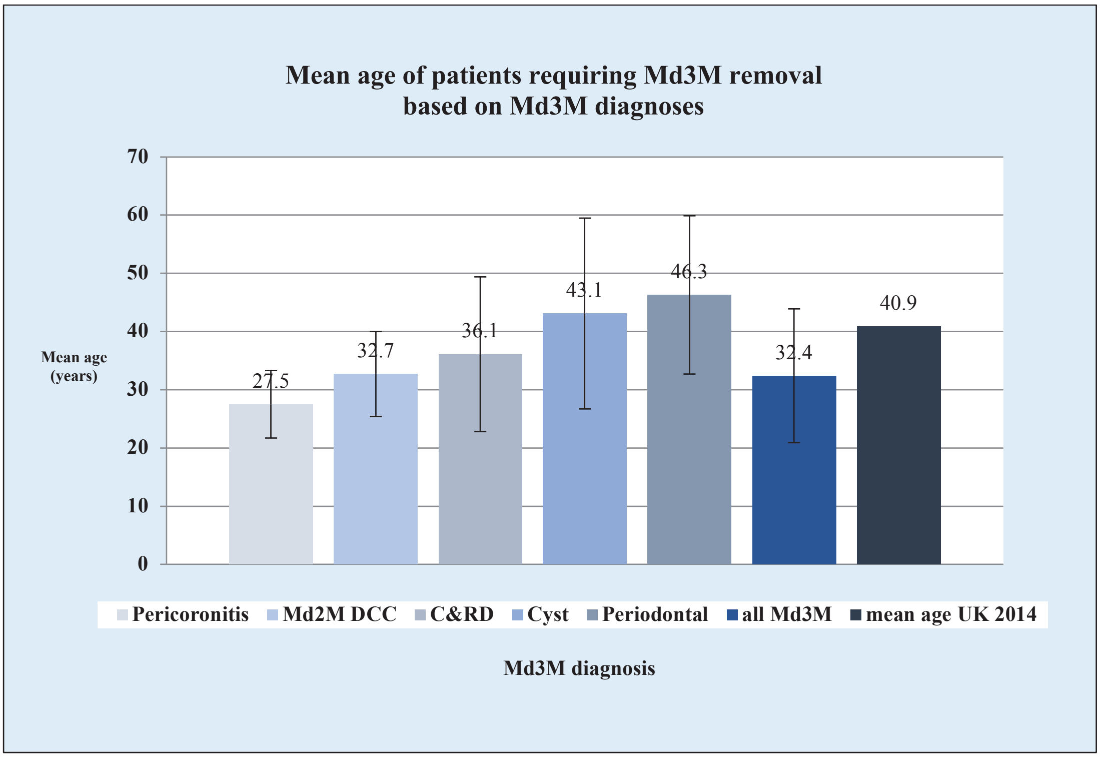
Figure 3.5 Mean age of patients requiring Md3M removal based on Md3M angulation of impaction.



Legend: *This figure illustrates the mean age of patients requiring Md3M removal based on angulation and impaction. For non-impacted vertical Md3M the mean age was 41.6 years, compared with mean ages of 28.6 years to 31.7 years for impacted Md3M (McArdle et al., 2018). (Standard Deviation bars illustrated for mean age, see text for values). (Mean age UK 2014 ONS, 2014b. ONS does not report SD for mean age).*

In terms of disease, for the most common diagnoses related to patients having a Md3M removed, the mean age of patients with a diagnosis of pericoronitis was 27.5 years (range 16-70 years, SD: 5.8 years); for C&RD, the mean age was 36.1 years (range 17-86 years, SD: 13.3 years); for periodontal disease, 46.3 years, (range 24-81 years, SD: 13.6 years); for Md2M DCC, 32.7 years, (range 21-55 years, SD: 7.3 years); and for dentigerous/odontogenic cyst, 43.1 years, (range 14-87 years, SD: 16.4 years). In relation to vertical impacted and *non-impacted* Md3M with a diagnosis of C&RD, the mean age of patients with a VERT(imp)Md3M was 31.9 years (range 19-65 years, SD: 9.6 years) and for a VERT(non)Md3M it was 39.7 years (range 17-83 years, SD: 14.7 years).

Figure 3.6 Mean age of patients requiring Md3M removal based on Md3M diagnoses.



Legend: *This figure illustrates mean age of patients requiring Md3M removed based on diagnoses. For pericoronitis the mean age was 27.5 years, Md2M DCC was 32.7 years and periodontal disease was 46.3 years (McArdle et al., 2018). (Standard Deviation bars illustrated for mean age, see text for values). (Mean age UK 2014 ONS, 2014b. ONS does not report SD for mean age).*

3.3 Discussion

3.3.1 The spectrum of disease and impactions

This study, as with other reported studies, reports pericoronitis as the most common indication for Md3M removal, with dental caries, cyst formation and periodontal disease being other common diseases associated with Md3M (Knutsson et al., 1996; van der Linden et al., 1995). The scope of impacted Md3M angulations in this study is similar to other studies (Bruce et al., 1980; Knutsson et al., 1996; van der Linden et al., 1995). Most Md3M studies do not, however, emphasise whether non-impacted Md3M are included in individual case-series or whether they have been incorporated as vertical impacted Md3M. The spectrum of disease related to non-impacted Md3M in this study is significantly different to the disease spectrum for impacted teeth and in a significantly older population ($p<0.001$).

When considering the disease spectrum of Md3M, it is important to consider Md3M disease in relation to each type of Md3M impaction rather than produce a summative account for all Md3M. By categorising disease in relation to Md3M impaction, we can reflect on the clinical significance that the nature of impaction may have on the potential disease outcome for patients.

3.3.2 Pericoronitis

Pericoronitis is the most common indication for the removal of Md3M as a whole (49%), but whereas it accounts for only 3% of $_{\text{VERT(non)}}$Md3M it accounts for 32% of $_{\text{MA}}$Md3M, 53% of horizontal impactions, 78% of vertical impactions and 84% of disto-angular impactions ($p<0.001$) (Figure 3.3). The reasons for the variation in pericoronitis related to the differing types of impaction may be explained by the local anatomy and the presence of an operculum of mucosa overlying the occlusal surface of vertical and disto-angular impactions. This would create a local environment conducive to local soft tissue infections secondary to poor or inadequate oral hygiene. Due to the inclination of a $_{\text{MA}}$Md3M this would tend to elevate the distal aspect of the crown away from the soft tissues eliminating the operculum and exposing the distal surface, which may then be more accessible to oral hygiene and a reduce risk of pericoronitis. Pericoronitis is rarely seen in vertically non-impacted Md3M primarily because there is no operculum that can become infected, hence pericoronitis is an uncommon feature and the tooth is retained as normal.

3.3.3 Caries and Related Disease (C&RD)

C&RD accounts for 27% of all Md3M extractions with C&RD in each of the main categories of impacted Md3M comparatively uniform. C&RD accounted for 15% of mesio-angular impactions, 12% of disto-angular impactions, 11% horizontal impactions and 16% of vertical impactions were removed due to C&RD. This suggests that the diagnosis and incidence of C&RD is independent on the type of Md3M impaction. However, compared with impacted Md3M, C&RD accounts for 85% of all VERT(non)Md3M removed ($p<0.001$) (Figure 3.3). Md3M C&RD has been shown to increase with age and VERT(non)Md3M tend not to be associated with the common diseases of impaction such as pericoronitis ($p<0.001$). In older middle-aged patient groups with retained Md3M, VERT(non)Md3M are more common than impacted third molars (Brickley et al., 1996). A VERT(non)Md3M would not be excluded from the potential of experiencing dental disease at some point but they would evade pericoronitis, remain functional and disease free for a period of time before a proportion of them succumb to typical dental disease such as caries and periodontal disease as reported here. This is supported by the observation that the mean age of patients with impacted Md3M with C&RD compared with non-impacted Md3M with C&RD is 31.9years compared with 39.7years respectively ($P<0.001$).

3.3.4 Mandibular Second Molar Distal Cervical Caries (Md2M DCC).

Md2M DCC, as an indication for Md3M removal, has been reported as contributing a relatively small proportion of Md3M removal in older studies (Bruce et al., 1980; Knutsson et al., 1996; McArdle and Renton, 2006; van der Linden et al., 1995). In this series it is not associated with vertical, disto-angular or ectopic impactions and its significance should not be considered collectively with all other types of Md3M impactions.

Md2M DCC in this study accounts for 14% of all Md3M removed and 17% of all impacted Md3M removed. It accounts for 9% of all horizontal impactions, however, Md2M DCC accounts for 44% of all MAMd3M removed.

The mean age of patients with Md2M DCC is 32.7 years compared with patients with pericoronitis (27.5 years) (p=0), with pericoronitis being the most common reason for Md3M removal. In this case series over 50% of all Md3M are removed in patients between 20-29 years of age suggesting that the majority of patients who will require Md3M removal will have lost them by the time they are 30 years old. This corroborates that Md2M DCC is a disease of older patients and, as pericoronitis is the most common indication for impacted Md3M removal, patients will generally succumb to other forms of disease such as this before Md2M DCC can occur (McArdle and Renton, 2006).

In addition to the loss of the Md3M to facilitate treatment of Md2M DCC, it has been reported that Md2M DCC has significant financial costs attributed to it and results in the eventual loss of 40% of Md2M. (McArdle et al., 2016) The primary risk factor related to Md2M DCC formation is the partially erupted mesio-angular or horizontally impacted Md3M and with such a high incidence of Md2M DCC in mesio-angular impactions consideration should be given to this disease's potential.

NICE advocated the proscription of prophylactic third molar removal in the late 1990s and the change in patient management had resulted in the mean age of patients requiring third molar removal increasing from 28 years to 32 years by 2009/10, with 30% of third molars removed due to dental caries as the primary indication for removal (McArdle and Renton, 2012). This 2012 data could not, however, differentiate between third molar caries and Md2M DCC. In this present study Md3M C&RD accounted for 14% of all impacted Md3M removed and Md2M DCC for 17% of impacted Md3M removed: in total 31% of all impacted Md3M were removed due to all categories of dental caries disease. With the addition of C&RD related to non-impacted Md3M, a total of 41% of Md3M were removed due to caries. Md2M DCC is the most common indication in this case series for the removal of a MAMd3M.

With 44% of all MAMd3M and 9% of all HORIZMd3M removed due to Md2M DCC concern is raised that observing and retaining an MAMd3M, in particular, until disease occurs may be an unsound management strategy. Contrary to NICE guidance early removal of MAMd3M and HORIZMd3M, in particular, may be indicated and should be considered so as to avoid Md2M DCC and its consequences.

3.3.5 Periodontal disease

Periodontal disease accounts for only 5% of all Md3M removed in this case series, however, it should be noted that only the *primary* indication for Md3M was recorded as opposed to all concomitant diseases that may have been associated with a particular Md3M. Nonetheless, periodontal disease was the primary indication for 12% of all HORIZMd3M and 9% of all VERT(non)Md3M, with smaller proportions for all other impacted Md3M. Periodontal disease is generally a quiescent disease that patients are often unaware of and generally only gives rise to significant symptoms in the later stages of the disease. Periodontal disease has been reported to be a clinical finding related to impacted third molars, however this data does not contradict these studies but may suggest that Md3M will become symptomatic and succumb to other Md3M diseases before periodontal disease becomes symptomatic and then the prime indicator for intervention (Blakey et al., 2006; Blakey et al., 2002; Elter et al., 2004a; Elter et al., 2004b; Elter et al., 2005; White et al., 2006).

3.3.6 Other Disease

All the remaining indications for Md3M removal collectively accounted for 4% of all indications and less than 1% individually. Some of these indications for third molar removal are interventional to facilitate other forms of treatment such as orthodontics orthognathic and dental implant treatment, others are uncommon such as internal or external resorption and others may be very weak indicators for removal, such as food packing. Food packing, and similar diagnoses, should not be dismissed as an indication for Md3M removal as these types of problems can be a constant source of irritation to a patient and the preference of the patient for the removal of the offending tooth is as valid a treatment option than any. Although a small number: 18 (1%) of Md3M were removed for the prevention of Md2M DCC, consideration has to be given to the weight of evidence for the potential for this disease to occur and for patients to be able to consider the options of intervening early or monitoring accordingly.

3.4 Age and Diagnoses

The mean age of patients requiring third molar removal was 32.4 years, however there was marked variation of patients' mean age based upon diagnoses. One-way ANOVA test was used to compare the mean ages of patients based on the most common diseases. Pericoronitis, with a mean age of patients 27.5 years; C&RD mean age 36.1 years; and Md2M DCC, mean age 32.7 years, when compared individually with each other, showed a statistically significant relationship (P=0).

The eruption of Md3M is generally accepted to occur between the ages of 18-24 years and the timing of disease presentation varies. Pericoronitis occurs frequently and relatively soon after failed eruption of the Md3M; It is the most common disease associated with impacted Md3M and in general occurs in younger age groups. Caries, in comparison, is a disease that will take time to develop before significant clinical signs and symptoms become present. As an indication for Md3M removal in all types of impaction, C&RD occurs more frequently in older age groups than pericoronitis. Likewise, Md2M DCC tends to occur in older patient groups but only with those with an impacted MAMd3M or HORIZMd3M.

3.5 Primary v Secondary Disease

The primary consequence of third molar impaction is the failure of the occlusion to reach the endpoint of maturity with the resultant dental malocclusion at the posterior aspect of the dental arch. An impacted tooth is a developmental anomaly and is defined as a disease by the WHO within the ICD10 classifications of diseases (K011) (WHO, 2016). Impaction is often overlooked as a disease in itself and the focus of defining third molar disease is often given to the consequent diseases of Md3M impaction, such as pericoronitis. However, the ***primary*** disease affecting the third molar is the impaction of the tooth and it is this which can then lead to consequential diseases such as pericoronitis, etc. These consequential diseases will generally occur ***secondary*** to the impaction, with patients experiencing a variety of differing disease. Where the third molar is erupted and functional, disease will not occur in the same manner as an impacted tooth. We should acknowledge that the impaction of the third molar is the *primary* disease that can then contribute to the development of *secondary* disease.

Only in the non-impacted Md3M can we consider that caries, periodontal disease, etc are the *primary* disease.

Variation in the characteristics of the Md3M contributes to when disease may occur and the type of disease that may occur. The capacity to understand the potential and the ability to anticipate third molar disease should guide clinical judgment in the management of patients. Understanding the spectrum and nature of disease in relation to impacted Md3M should allow better management of individual patients with impacted Md3M. Patients with third molars cannot be managed as a collective group as this can have negative outcomes especially in relation to diseases such as Md2M DCC.

The prevalence of impacted third molars in the general population as a whole has been reported to be approximately 25% (Carter and Worthington, 2016). This number is misleading as it would appear to include everyone, including people who have had third molars removed. This miscalculates the true prevalence as it mistakenly presumes that if a patient has no third molars that they never had any previously. It has been reported that the prevalence of impacted third molars in 20-30 year olds is over 70% (Hugoson, 1988). It has also been reported that for those patients in middle-age only 13% retain an impacted Md3M (Brickley et al., 1996). Although these two later studies are not related, if these studies are representative of patients then 80% of patients with impacted third molars will have undergone third molar removal by the time they are middle-aged (McArdle et al., 2018). With such a high potential proportion of the adult population requiring third molar removal consideration should be given to addressing the potential for secondary disease rather than solely addressing secondary disease when it occurs.

3.6 Conclusions

Md3M can display a wide spectrum of disease that varies with some diseases appearing to be dependent on the type of Md3M impaction such as Md2M DCC, and independent of the impaction such as pericoronitis and C&RD. Disease occurs in non-impacted Md3M as well as impacted Md3M with diseases affecting non-impacted teeth tending to be the typical dental diseases of caries and periodontal disease though in an older patient population. Diseases related to impacted teeth reflect the more specific diagnoses of pericoronitis, Md3M caries and Md2M DCC, and in a younger patient population.

The variation of disease and the mean-age of patients seen in the differing types of impaction is significant in that some diseases, such as Md2M DCC, will occur dependent upon the angulation of impaction, and others, such as C&RD, independent of the angulation. Younger patients are more affected by disease such as pericoronitis and less so by other diseases such as C&RD, whereas older patients are more affected by C&RD and Md2M DCC.

Md2M DCC accounts for 44% of all mesio-angular impacted and 9% of horizontally impacted Md3M removed. The risk factors for the development of Md2M DCC have been previously reported (McArdle and Renton, 2006; Nunn et al., 2013; Ozeç et al., 2009; Toedtling et al., 2016). Early intervention in patients with impacted Md3M at risk of causing Md2M DCC should be considered and consequently prophylactic intervention may have role to play in the management of patients at risk of DCC of the Md2M.

Chapter 4

The characteristics of disease related to mesio-angular and horizontal mandibular third molars: the causative third molars for mandibular second molar distal cervical caries.

Aspects of this chapter were published as:

McArdle LW, Jones J, McDonald F. **Characteristics of disease related to mesio-angular mandibular third molar teeth.** British Journal of Oral and Maxillofacial Surgery. 2019; **57**:306-311.

4.1 Introduction

The mesio-angular mandibular third molar tooth (MAMd3M) is the most common type of mandibular third molar (Md3M) impaction and can contribute to a variety of common diseases such as pericoronitis, dental caries and periodontal disease (Adeyemo et al., 2008; Knutsson et al., 1996; McArdle et al., 2018; Nordenram et al., 1987; Pratt, et al., 1998; Stanley et al., 1988; van der Linden et al., 1995). As previously highlighted, the partially erupted MAMd3M can also result in Distal Cervical Caries (DCC) of the mandibular second molar tooth (Md2M) which can have significant clinical consequences for the patient (Chang et al., 2009; McArdle and Renton, 2006; McArdle et al., 2014; Nunn et al., 2013; Oderinu et al., 2012; Ozeç et al., 2009; Toedtling et al., 2016). The MAMd3M accounts for approximately 91% of all cases of Md2M DCC with the HORZMd3M accounting for approximately 9%. Although Md2M distal caries has been reported in other classifications of impacted Md3M, these papers have included interproximal caries rather than solely DCC. DCC was not observed in any other classification of Md3M impaction in this dataset and is not observed in the absence of an impacted Md3M. It has been demonstrated that that up to 40% of Md2M are lost due to Md2M DCC, with the remaining 60% requiring restoration (McArdle et al., 2016). The long-term consequences for those Md2M that are restored due to DCC is unknown, however the long-term failure of restored Md2M should be expected leading to further loss of the Md2M over time. The incidence of Md2M DCC has been reported to vary from between 2% and 14% of patients having Md3M removed, however, these figures relate to all categories of Md3M rather than to the specific type of impaction associated with it (Brickley et al., 1996; Bruce et al., 1980; Chu et al., 2003; McArdle at al, 2018; McArdle and Renton, 2012; Pepper et al., 2017).

As previously suggested a diagnosis of Md2M DCC highlights the potential risk of DCC forming on a disease free Md2M associated with a partially erupted MAMd3M. If all, or a significant proportion of, partially erupted MAMd3M or HORZMd3M pose a risk then the case for early intervention and prophylactic removal of both should be considered, as the risk and cost of retention of the Md3M resulting in Md2M DCC will be greater than the early removal (McArdle et al., 2016). Consequently, NICE's guidance may be in conflict with the reality of long-term retention of impacted third molars, especially the MAMd3M and the latent potential for Md2M DCC to occur. As demonstrated 44% of all MAMd3M are removed due to Md2M DCC, however 56% are removed for other clinical indications. Not all Md2M associated with an impacted MAMd3M or HORZMd3M experience DCC which consequently challenges whether prophylactic removal of MAMd3M and HORZMd3M should be universal as we cannot determine if all patients will be affected by the disease in the long term.

4.1.1 Aims

The principle aim of this chapter was to independently evaluate two cohorts of patients who had MAMd3M and HORZMd3M removed; to identify the patient and Md3M characteristics and in particular to determine the clinical diagnoses and to ascertain if there was any age-related disease variation for MAMd3M and HORZMd3M removal based on 5 year age cohorts of patients. Furthermore, to consider the diagnoses in relation to patients' dental health as measured by the DMFT score (Decayed, Missing or Filled Teeth).

4.1.2 Ethics

The local ethics committee of KCL Dental Institute was approached for advice regarding the need for ethical approval and as data collection would neither identify individual patients nor influence treatment or outcomes, formal ethical approval was not required.

4.1.3 Methodology

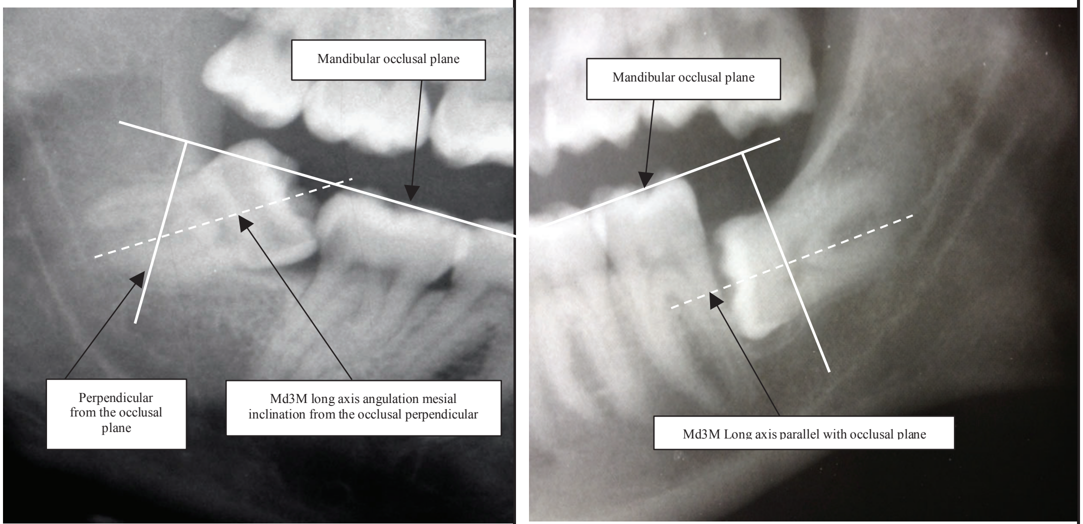
Data from the main database of 1011 patients attending for Md3M removal was evaluated to identify patients who had a MAMd3M or HORZMd3M tooth removed (McArdle et al., 2018). All patients having a MAMd3M and HORZMd3M removed were isolated from the main database into two cohorts and the recorded data for each MAMd3M and HORZMd3M patient cohort was independently evaluated. Of these 1011 patients, 319 were identified who had had at least one MAMd3M removed and 151 patients who had at least one HORZMd3M removed.

The recorded variables assessed were; age, patient gender, the angulation of impaction of the Md3M, the primary indication for removal of the Md3M tooth, and the DMFT score as a basic measurement of dental health.

Mesio-angular and horizontal angulation of the Md3M was defined by standard convention (Figure 4.1) . Mesio-angulation was defined as the mesial, or forward, angulation of the Md3M from the occlusal perpendicular; in effect, where the mesial tilt of the Md3M was greater than zero degrees and less than 90 degrees (Figure 4.1.i). Where the long axis of the Md3M was parallel with the mandibular occlusal plane the angle was defined as horizontal (Figure 4.1.ii).

Figure 4.1 Calculating the angulation of impaction of the Md3M.

4.1.i. Mesio-angular Md3M. 4.1.ii. Horizontal Md3M.



Legend: *This image demonstrates the method of calculating the mesial and horizontal inclination of the Md3M. The angle of intersection of the mandibular occlusal plane and the occlusal plane of the Md3M is equal to the mesial inclination of the Md3M relative to the vertical inclination of the mandibular teeth. The*

For each angulation cohort the number of Md3M teeth removed was calculated along with the proportion for each diagnosis. The mean age of patients as it related to each individual angulation and principal diagnosis was calculated. Principal diagnoses included pericoronitis, C&RD, Md2M DCC, periodontal disease and odontogenic cyst. Patients from each angulation cohort were subdivided into 5 year age groups and the frequency of disease as it related to Md3M angulation within these age groups was calculated.

The DMFT of patients was also calculated for 10 year age groups matched to the 2009 ADHS (ADHS, 2011). The mean DMFT was calculated as it related to each age group matched angulation cohort and each of the principal diagnoses for each angulation. The DMFT of the general population was calculated from the 2009 ADHS (ADHS, 2011). The Adult Dental Health Survey of 2009 published data on the average number of sound, unrestored teeth of patients within given age groups, whereas previous Adult Dental Health Surveys had published the average DMFT scores for patients (ADHS, 2000; ADHS 2011). Email communication with the Office of National Statistics and the authors of the 2009 ADHS confirmed that the calculation of average DMFT scores based on the results of the 2009 ADHS could be calculated by subtraction of the average value for sound, unrestored teeth from 32; the number of teeth within a fully dentate individual (Triffit, 2012).

Data related to defining Md3M disease reflected that of the main database, in that all variants of pericoronitis were ascribed to a single diagnostic group defined as ‘pericoronitis’ and patients whose third molar was removed due to dental caries, or the consequences of dental caries, such as dental abscess or per-apical abscess, were ascribed to the diagnostic group of caries and related disease (C&RD).

4.1.4 Statistical analysis.

As previously defined, the original sample size was calculated by power calculator (Gpower 3.1.9.2) allowing for a confidence level of 95% with a 5% margin of error (low effect size of 0.1, with a power level of 80% and alpha level of p=0.05). Patient variables were identified as previously described (see 3.1.4). Total sample size calculation for all independent variables was determined at 969 however a total of 1011 patients were eventually assessed.

The sample and outcome characteristics were summarised using descriptive statistics. Sample means, number, range and standard deviation were calculated for patient age related to Md3M angulation and Md3M disease diagnoses. Angulation related frequency and distribution of disease was also calculated. Sample means, number, range and standard deviation were calculated for DMFT for age matched groups. The mean age of patients for different disease presentation and for Md3M impaction status were compared using one way ANOVA. Statistical significance was assumed at 5% level and analyses were carried out using SPSS version 23.0 and MedCalc software.

4.2 Results MAMd3M

Of the 319 patients who had a MAMd3M removed, 225 patients had a single MAMd3M removed and 94 patients had bilateral removal; a total of 413 MAMd3M removed. The mean age of all patients was 30.1 years, (n=319, SD: 7.7 years range 12-67 years).

4.2.1 Disease related to MAMd3M

The most common indication for the removal of a MAMd3M was Md2M DCC, accounting for 180 (44%) of all MAMd3M removed with 33 patients having bilateral MAMd3M removal due to bilateral Md2M DCC. Pericoronitis accounted for 131(32%) of all MAMd3M removed; C&RD for 62 MAMd3M (15%); periodontal disease for 13 MAMd3M (3%), odontogenic cyst for 5 MAMd3M (1%); orthodontic/orthognathic indications for 5 MAMd3M (1%); and external resorption for 2 MAMd3M (<1%). Additionally, a total of 14 (3%) MAMd3M were prophylactically removed due to potential risk to of Md2M DCC.

Md2M DCC, pericoronitis, C&RD, odontogenic cyst and periodontal disease were defined as the *principal* disease indicators as they are the most significant in terms of frequency and clinical significance. Only these disease indicators for MAMd3M are included in the descriptive analysis as the frequency of the others spread across the age cohorts do not demonstrate any statistical significance (Figure 4.2)

Figure 4.2. Percentage distribution of disease/principal indication for MAMd3M removal for 413 MAMd3M in 319 patients (225 unilateral and 94 bilateral)

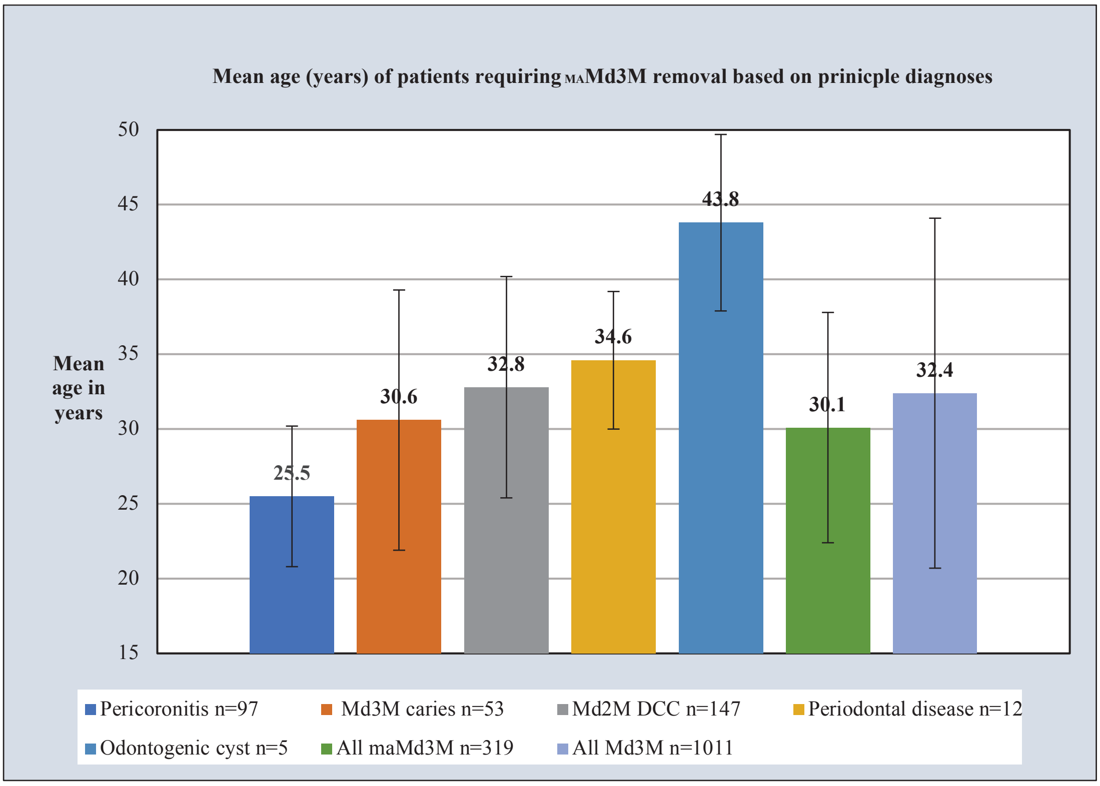
DIAGNOSIS FOR MAMd3M REMOVAL	NUMBER OF MAMd3M REMOVED	PERCENTAGE DISTRIBUTION (%)
1 – Md2M DCC	180	44%
2 – Pericoronitis	131	32%
3 – Caries & Related Disease (C&RD)	62	15%
4 – Periodontal disease	13	3%
5 – Prevention DCC 2nd molar	14	3%
6 – Odontogenic cyst	5	1%
7 – Pre-orthodontic/orthognathic	5	1%
8 - External resorption of 2nd molar	4	0.3%
9 – Prophylactic secondary to GA	1	0.2%
Total number of MAMD3M removed	413	100%

Legend: *This table demonstrates the percentage distribution of diseases associated with the removal of 413 MAMd3M. Md2M DCC is the most common indication for the removal of MAMd3M.*

4.2.2 Age and Disease MAMd3M

For the principal diagnoses related to patients having a MAMd3M removed, the mean age of patients with a diagnosis of pericoronitis was 25.5 years (n=97, SD: 4.7 years, range 17-38 years); for C&RD the mean age was 30.6 years (n=53, SD: 8.7 years, range 18-67 years); for Md2M DCC, 32.8 years (n=147, SD: 7.4 years, range 21-55 years); for periodontal disease, 34.6 years (n=12, SD: 4.6 years, range 24-40 years): and for odontogenic cyst, 43.8 years (n=5, SD 5.9 years, range 38-53 years) (Figure 4.3).

Figure 4.3. Mean age (years) of patients requiring MAMd3M removal based on principal diagnoses.



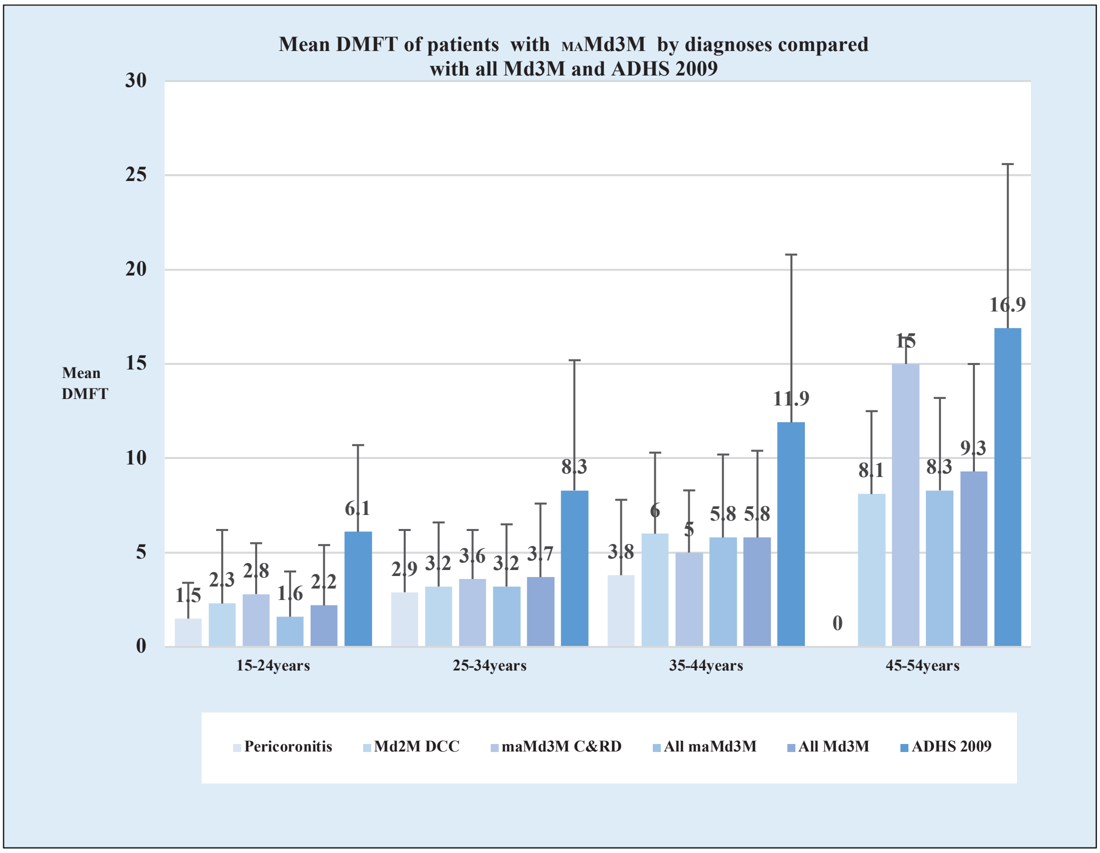
Legend: *the mean age of patients (in years) requiring MAMd3M removal based on the principal diagnoses and compared with all Md3M removed. This graph demonstrates that, for the most common diseases, the mean age of patients who had MAMd3M removed varies with the type of disease. Patients who had pericoronitis are significantly younger than patients with Md3M caries (p<0.001; d.f. 149, F=21.8) or patients with Md2M DCC (p<0001; d.f. 243, F=74.5) (McArdle et al., 2019). (Standard Deviation bars illustrated for mean age, see text for values).*

4.2.3 DMFT MAMd3M

The mean DMFT was calculated for patients who had MAMd3M removed due to pericoronitis, Md2M DCC, and C&RD, and for 10 year age-ranges to allow comparison with the 2009 Adult Dental Health Survey (ADHS) (Figure 4.4) (HMSO, 2011). In addition, the mean DMFT was calculated for all patients from the larger study of 1011 patients, having all Md3M removed for the same 10 year age ranges (McArdle et al., 2018).

For the most common MAMd3M diseases, the mean DMFT for each 10 year age-range was comparable with each other. For each 10 year age-range, all patients having a MAMd3M removed had a mean DMFT score comparable with the mean DMFT of all Md3M removed but approximately 50% less than the comparable age range mean DMFT from the ADHS 2009 (Figure 4.4). Similarly, the mean DMFT score of patients, based on the main diagnoses was approximately 50% less compared with the ADHS. The only exception to this was patients in the 45-54 age range with a diagnosis of C&RD, who had a mean DMFT comparable to patients from the ADHS 2009.

Figure 4.4. Mean DMFT of patients with MAMd3M based on principal diagnoses compared with all Md3M and ADHS 2009.

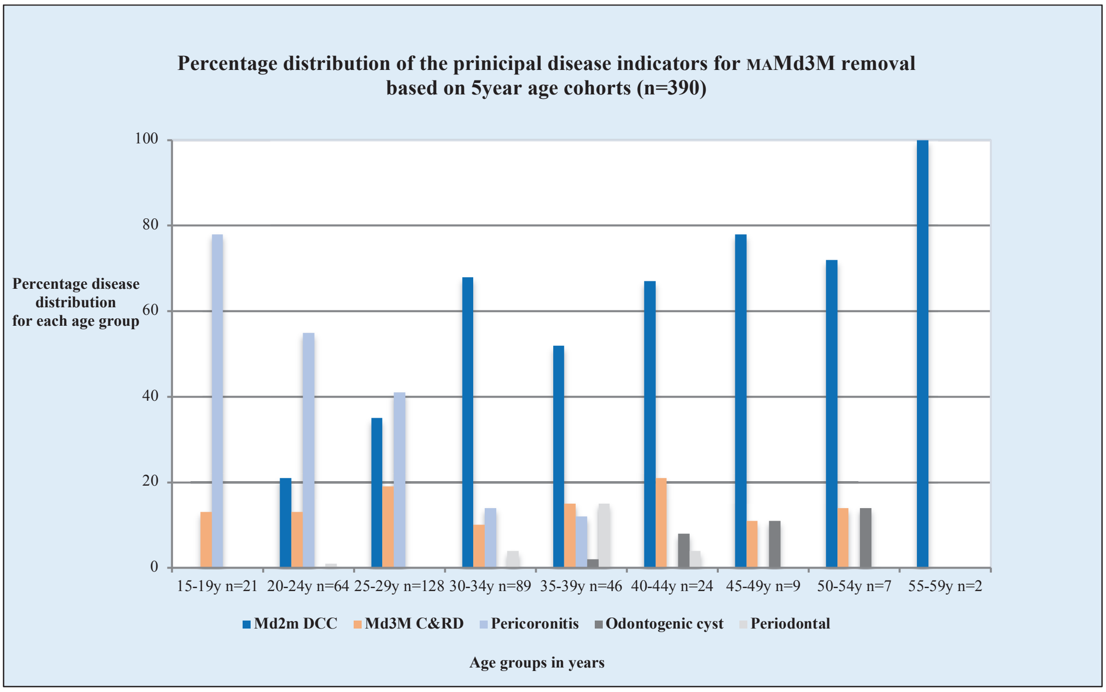


Legend: *The mean DMFT score of patients requiring MAMd3M removal based on principal diagnoses and all MAMd3M compared with all Md3M removed and the ADHS 2009. (Data labels report each DMFT value). This graph demonstrates that, for the most common diseases, the mean DMFT of patients who had MAMd3M removed were comparable with all patients requiring Md3M removal, though approximately 50% lower than the AHDS 2009 for comparable age groups (McArdle et al., 2019). (Standard Deviation bars illustrated for mean age, see text for values).*

4.2.4 Disease Distribution MAMd3M

The distribution of the principle MAMd3M diseases was also considered in relation to the age cohorts of patients (Figure 4.5). In younger age groups pericoronitis was the most common indication for the removal accounting for 78% of all MAMd3M removed in 15-19 years olds (n=18); 55% of 20-24 year olds (n=39); 41% of 25-29 year olds (n=55), and 14% of 30-34 year olds (n= 13). Md3M C&RD ranged between 10-20% in all age groups from 15-19 years through to 50-54 years. Md2M DCC was not seen in patients under the age of 20 years, however the proportion of Md2M DCC as the primary indication for MAMd3M removal in 20-24 year olds was 20% (n=15 MAMd3M), rising to 35% in 25-29 year olds (n=47 MAMd3M) and 68% of 30-34 year olds (n=63 MAMd3M). The proportion of MAMd3M removed due to Md2M DCC in each of the older groups averaged in excess of 60%, however, the total number of patients within each of these older groups decreased with age as the total number of patients retaining third molars as a proportion of their peer group into later life contracts.

Figure 4.5 Percentage distribution of principal disease indicators for MAMd3M removal based on 5 year age cohorts (n=390).



Legend: *A total of 413 MAMd3M were removed from the cohort of 319 patients. This graph demonstrates those 390 MAMd3M with the most common diseases as opposed to all diseases. The proportion of MAMd3M removed due to pericoronitis reduces as patients become older and conversely the proportion of MAMd3M removed due to Md2M DCC increases with age. These other indicators constituted a small proportion of patients and offered no descriptive analysis. Age range of all patients is 12-67 years, age range of patients with principal disease indicators is 17-67 years (one single MAMd3M was removed in a 67 year old patient and not displayed of graph) (McArdle et al., 2019).*

4.4 Results HORZMd3M

Of the 151 patients who had a HORZMd3M removed, 104 patients had a single HORZMd3M removed and 47 patients had bilateral removal; a total of 198 HORZMd3M were removed. The mean age of all patients was 31.7 years, (n=151, SD: 10.3 years, range 14-87 years).

4.4.1 Disease HORZMd3M

The most common indications for the removal of a HORZMd3M was pericoronitis, accounting for 106 (53%) of all HORZMd3M removed. C&RD accounted for 22 HORZMd3M (11%); periodontal disease for 25 HORZMd3M (13%), Md2M DCC accounted for 18 (9%) of all MAMd3M removed with 2 patients having bilateral MAMd3M removal due to bilateral Md2M DCC. Odontogenic cyst accounted for 16 HORZMd3M (8%) with orthodontic/orthognathic indications for 4 HORZMd3M (2%). Additionally, a total of 3 (1%) MAMd3M were prophylactically removed due to potential risk of Md2M DCC and for all other indications 4 (2%) HORZMd3M were removed.

Pericoronitis, periodontal disease, C&RD, Md2M DCC, and odontogenic cyst were defined as the *principal* disease indicators as they are the most significant in terms of frequency and clinical significance. Only these disease indicators for HORZMd3M are included in the descriptive analysis as the frequency of the others spread across the age cohorts do not demonstrate any analytical significance (Figure 4.6).

Figure 4.6. Percentage distribution of disease/principal indication for HORZMd3M removal for 199 HORZMd3M in 151 patients (105 unilateral and 47 bilateral).

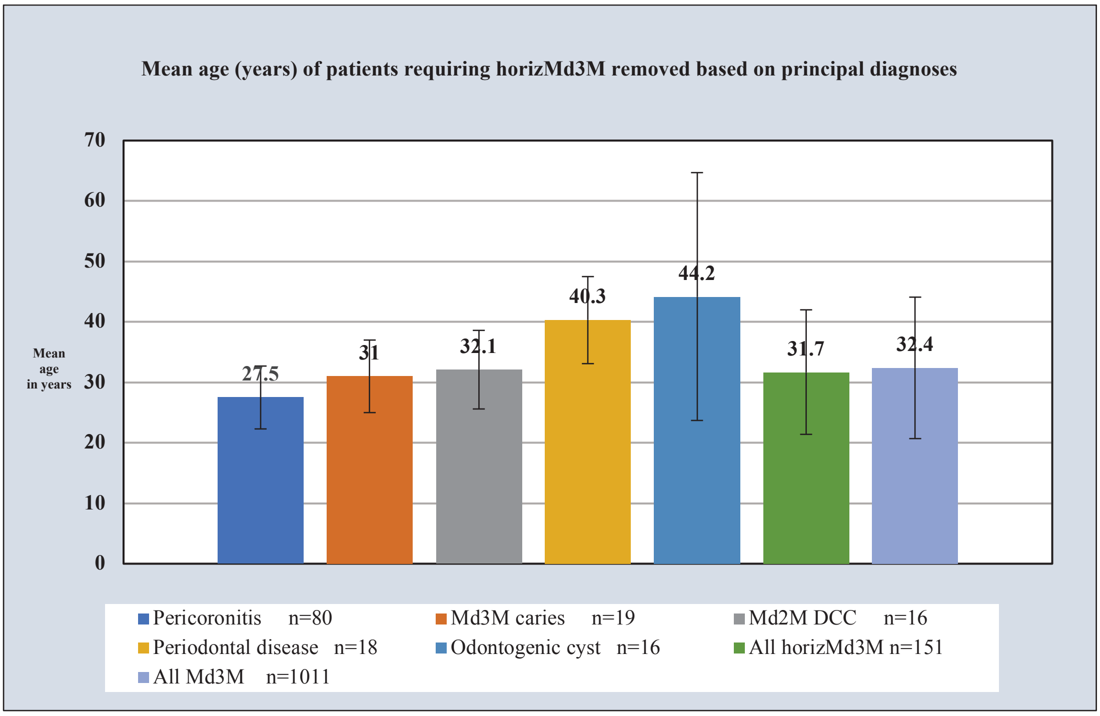
DIAGNOSIS FOR zMd3M REMOVAL	NUMBER OF horzMd3M REMOVED	PERCENTAGE DISTRIBUTION (%)
1 – Pericoronitis	106	53%
2 – Periodontal disease	25	13%
3 – Caries & Related Disease (C&RD)	22	11%
4 – Md2M DCC	18	9%
5 – Odontogenic cyst	16	8%
6 – Pre-orthodontic/orthognathic	4	2%
7 – Prevention Md2M DCC	3	1%
8 - all other indications combined	4	2%
Total number of HORZMD3M removed	198	100%

Legend: *This table demonstrates the percentage distribution of diseases associated with the removal of 413 HORZMd3M. Md2M DCC is the most common indication for the removal of MAMd3M.*

4.4.2 Age and Disease HORZMd3M

For the principal diagnoses related to patients having a HORZMd3M removed, the mean age of patients with a diagnosis of pericoronitis was 27.5 years (n=80, SD: 5.2 years, range 17-44 years); for C&RD the mean age was 31 years (n=19, SD: 6 years, range 20-42 years); for Md2M DCC, 32.1 years (n=16, SD: 6.5 years, range 22-46 years); for periodontal disease, 40.3 years (n=18, SD: 7.2 years, range 32-57 years): and for odontogenic cyst, 44.2 years (n=16, SD 20.5 years, range 14-87 years) (Figure 4.7).

Figure 4.7. Mean age (years) of patients requiring HORZMd3M removal based on principal diagnoses.



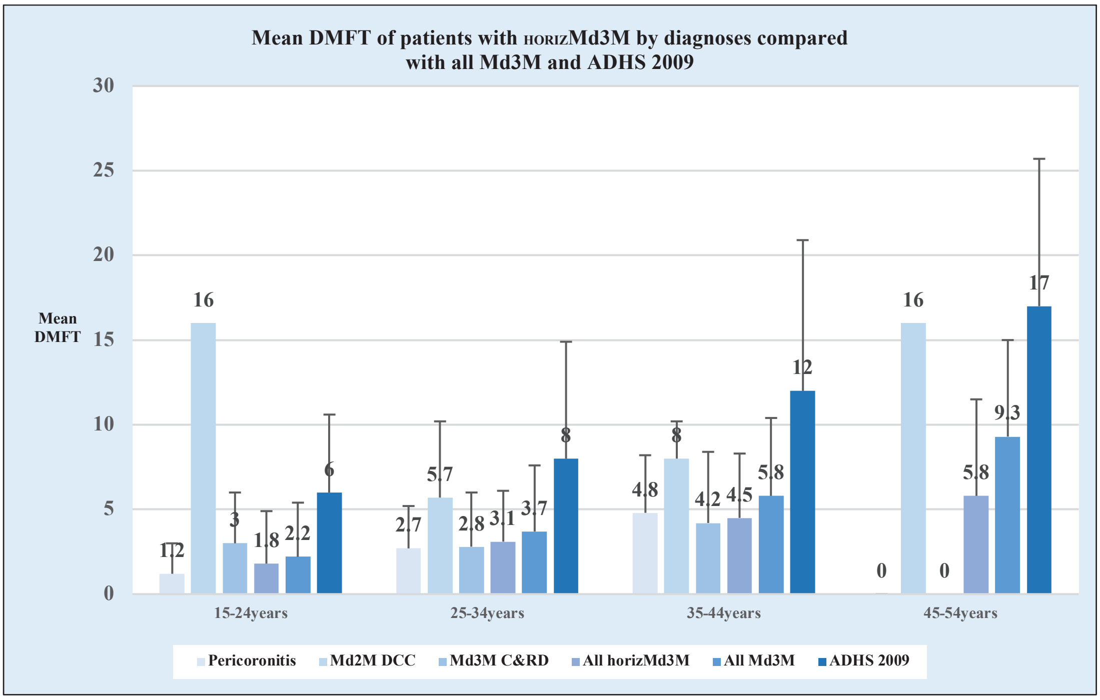
Legend: *the mean age of patients (in years) requiring HORZMd3M removal based on the principal diagnoses and compared with all Md3M removed.* [3.] *This graph demonstrates that, for the most common diseases, the mean age of patients who had HORZMd3M removed varies with the type of disease. Patients who had pericoronitis are significantly younger than patients with Md3M caries (p=0.012; d.f. 98, F=6.55) or patients with Md2M DCC (p=0.0026; d.f. 95, F=9.57). (Standard Deviation bars illustrated for mean age, see text for values).*

4.4.3 DMFT HORZMd3M

The mean DMFT was calculated for patients who had HORZMd3M removed due to pericoronitis, Md2M DCC, and C&RD, and for 10 year age-ranges to allow comparison with the 2009 Adult Dental Health Survey (ADHS) (Figure 4.8) (ADHS, 2011). In addition, the mean DMFT was calculated for all patients from the larger study of 1011 patients, having all Md3M removed for the same 10 year age ranges (McArdle et al., 2018).

For the most common HORZMd3M diseases, the mean DMFT for each 10year age-range was comparable with each other. For each 10 year age range, all patients having a HORZMd3M removed had a mean DMFT score approximately 50% less than the comparable mean DMFT from the ADHS 2009 (Figure 4.8). Similarly, the mean DMFT score of patients, based on the main diagnoses was approximately 50% less compared with the ADHS. The only exception to this was patients in the 45-54 year age range with a diagnosis of C&RD, who had a mean DMFT comparable to patients from the ADHS 2009.

Figure 4.8. Mean DMFT of patients with HORZMd3M based on principal diagnoses compared with all Md3M and ADHS 2009.

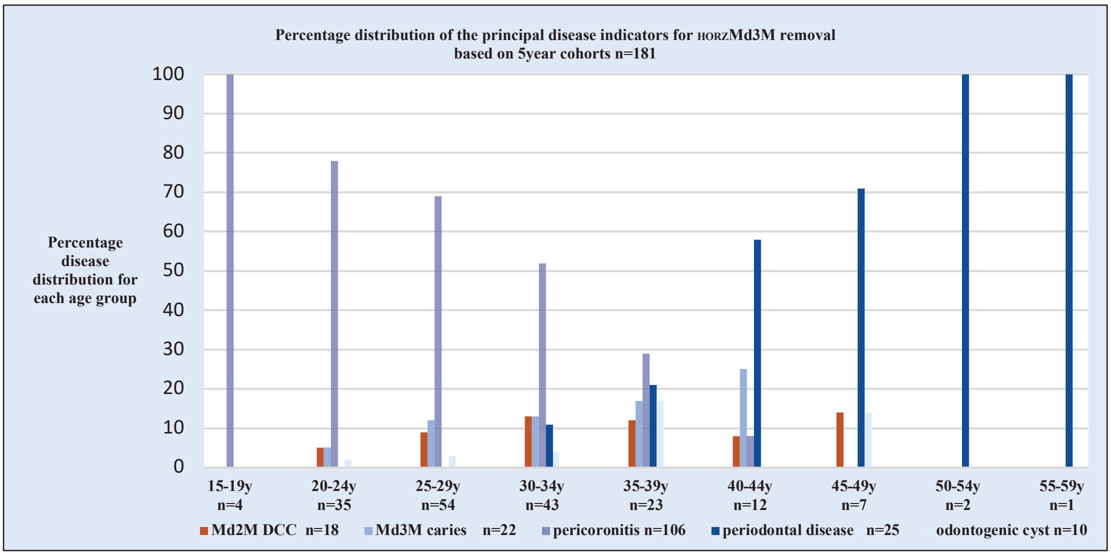


Legend: *The mean DMFT score of patients requiring HORZMd3M removal based on principal diagnoses and all HORZMd3M compared with all Md3M removed and the ADHS 2009. (Data labels report each DMFT value). This graph demonstrates that, for the most common diseases associated with HORZMd3M, the mean DMFT of patients were comparable with all patients requiring Md3M removal, though approximately 50% lower than the AHDS 2009 for comparable age groups. The Md2M DCC DMFT value for the 15-24 year age group and the 45-54 year age group relate to a single patient and offers no statistical deviation value). There were no patients in the 45-54 age group who had an HORZMd3M removed due to pericoronitis or Md3M C&RD. (Standard Deviation bars illustrated for mean age, see text for values).*

4.4.4 Disease Distribution HORZMd3M

The distribution of the principle diseases related to HORZMd3M was also considered in relation to the age cohorts of patients (Figure 4.9). In younger age groups pericoronitis was the most common indication for the removal accounting for 73% of all HORZMd3M removed in patients under the age of 30years of age (n=102). In patients over the age of 30 years pericoronitis tapers in its frequency and accounts for 33% of all HORZMd3M removed with the majority of HORZMd3M in the 30 years plus age group being removed before the age of 35 years. The graph in figure 4.9 demonstrates a tapering reduction in frequency of pericoronitis as patients become older. Md3M C&RD demonstrated an increasing frequency as patients became older whereas the frequency of Md2M DCC appeared to be relatively uniform in frequency in older age groups and ranged between 10-20% in all age groups from 15-19 years through to 50-54 years. Periodontal disease was the second most common disease attributable to the removal of the HORZMd3M and represented an increasing proportion of HORZMd3M removed in older aged groups. The numbers of HORZMd3M removed totalled 198 with 105 HORZMd3M removed due to pericoronitis. The fractionalised volume and spread of HORZMd3M removed across the age spectrum for each disease becomes relatively small for each age cohort. Consequently, the true descriptive statistical picture may not permit an accurate interpretation.

Figure 4.9. Percentage distribution of principal disease indicators for HORIZMd3M removal based on 5 year age cohorts (n=181).



__Legend:__ A total of 198 MAMd3M were removed from the cohort of 151 patients. This graph demonstrates those 181 HORZMd3M with the most common diseases as opposed to all diseases. The other indicators constituted a small proportion of HORZMd3M and offered no descriptive analysis. The number of HORZMd3M removed due to Md2M DCC is small but the proportion removed is comparable in each of age group cohort; similarly with Md3M caries and related disease. range of all patients is 14-87 years, age range of patients with principal disease indicators is 17-57 years.

4.5 Discussion.

Pericoronitis is commonly reported as the main indication for the removal of Md3M and is the most commonly reported indication for the removal of MAMd3M (Brickley, 1996; Knutsson et al., 1996; Nordenram et al., 1987). However in this study the primary indication for MAMd3M removal was Md2M DCC, accounting for 44% of all MAMd3M. In contrast with the MAMd3M, the HORZMd3M had a relatively low frequency of Md2M DCC of approximately 9% (McArdle et al., 2018).

It has been previously demonstrated that as the mean age of patients increases, the frequency of caries and its variants (C&RD) also increases as the primary indicator for Md3M removal (McArdle and Renton, 2012). Furthermore, the increased frequency of Md2M DCC seen now in patients can also be attributed to the fact that patients having Md3M removal are presenting later in life than previously reported with a different spectrum of disease (McArdle and Renton, 2012). In younger patients, Md2M DCC is seen infrequently as this disease will generally take a long period of time to develop after failed eruption of the third molar (Bruce et al., 1980; McArdle and Renton, 2006). The overall low incidence of Md2M DCC in studies where prophylactic removal is common and the consequent mean age of patients is younger conceals the true potential of Md2M DCC as early removal will eliminate its potential (Brickley and Shepherd, 1996; Worrall et al, 1998). Now that early prophylactic removal is proscribed and Md3M are retained for longer, the opportunity for Md2M DCC to develop is established and an increase in frequency is observed in patients who are consequently older.

For patients with MAMd3M, the mean age of patients with pericoronitis was 25.5 years compared with 30.6 years for C&RD ($P<0.0001$; d.f. 149, $F=21.8$) and 32.8 years for Md2M DCC ($P<0.0001$; d.f. 243, $F=74.5$). Likewise, for HORZMd3M, the mean age for patients with pericoronitis was 27.5 years and was lower than for both C&RD (mean age 31 years. $p=0.012$; d.f. 98, $F=6.55$) and for Md2M DCC (mean age 32.1 years. $p=0.0026$; d.f. 95, $F=9.57$). The significant difference in mean age of patients with pericoronitis endorses that pericoronitis is principally a disease of younger patients and is seen relatively soon after failed eruption of the Md3M (Figures 4.3 and 4.7).

Based on the master database, 55% of all MAMd3M are removed before the age of 30 years of age with pericoronitis being the most common indication for their removal (49%). In comparison, Md2M DCC accounts for 27% of all MAMd3M in the under 30s but 65% in the over 30s age groups. Pericoronitis accounts for only 10% of all MAMd3M removed in the over 30s with the majority of these being in the 30-34 age range (Figure 4.5). C&RD accounts for approximately 15% of all MAMd3M requiring removal, however, the frequency of C&RD compared between each of the age cohorts remains relatively uniform (range10-20%). This increase in frequency of Md2M DCC as patients become older has been suggested previously but these studies either did not reflect nor compare with other clinical indications for Md3M removal or that the age groups were incomparable (Bruce et al., 1980; Ozeç et al., 2009). It is noteworthy that for MAMd3M and HORZMd3M, the frequency of C&RD remains relatively constant for each of the age ranges but the frequency of Md2M DCC related to MAMd3M does not correspond with this even though both diagnoses are caries related. As patients become older, the frequency of Md2M DCC associated with MAMd3M increases. It is significant as it suggests that DCC will form on a substantial majority of Md2M associated with a retained MAMd3M the longer that they are left.

The majority of MAMd3M are removed before the age of 30 years primarily due to pericoronitis. This substantial loss of MAMd3M leaves an ever-decreasing pool of older patients retaining their MAMd3M. However, it is these patients who will potentially succumb to the possibility of Md2M DCC. As patients get older, the incidence of pericoronitis as the main indicator for MAMd3M removal demonstrates a tapering linear decline, whereas a reciprocal linear increase in Md2M DCC is observed as patients become older (Figure 4.5). Most patients with a MAMd3M will succumb to pericoronitis before the potential of Md2M DCC can be realized but those patients who retain their MAMd3M into later life are at significant risk of Md2M DCC developing. All partially erupted MAMd3M pose a substantial risk to the Md2M for the formation of DCC, the fact that we do not observe it in all cases is due to the fact that a significant proportion of MAMd3M are removed before Md2M DCC can occur. In contrast the frequency of Md2M DCC associated with HORZMd3M is 9% in total but across the older aged cohorts, accounts for approximately 10% of HORIZMd3M removed in each of the four age-groups between 25 and 49 years. Unlike with MAMd3M there is no increase in frequency of Md2M DCC for patients with

HORZMd3M as they become older. This makes predicting the potential for Md2M DCC in HORZMd3M problematic compared with the potential with MAMd3M where the frequency increases with age. The numbers of patients with HORZMd3M removed due to Md2M DCC is relatively small however (16 patients with 18 HORZMd3M removed), and a larger patient group dataset would ideally be required to assess this further.

It has been previously reported that mean DMFT scores of patients with Md2M DCC are approximately 50% less than mean DMFT scores for comparable age matched control groups when compared with the AHDS 2009 age matched control groups (McArdle and Renton, 2006; McArdle et al., 2014). This suggested that patients with low DMFT scores may be more likely to experience Md2M DCC, as low scores suggested better oral hygiene; a reduced likelihood of pericoronitis, and consequent retention of the MAMd3M into later life. In this study, the mean DMFT scores for patients with Md2M DCC were similarly, 50% lower for similar age groups when compared with the 2009 ADHS. (ADHS, 2011) However, for all the main types of disease associated with both MAMd3M and HORZMd3M, the mean DMFT scores of patients, for similar age groups, was also approximately 50% less than the 2009 ADHS (Figures 4.4 and 4.8).

Good dental health, as measured by DMFT cannot, therefore, be used as a predictor of any specific Md3M disease and suggests that all patients with Md3M are at risk of experiencing disease rather than implying that patients with better dental health are more prone or less prone to third molar disease. Low DMFT scores cannot, therefore, be used to refute the possibility of third molar disease occurring.

The relative incidence of Md2M DCC in patients requiring Md3M removal has been reported to be between 4% to 14% (Brickley et al., 1996; Bruce et al., 1980; Chu et al., 2003; McArdle et al., 2018; McArdle and Renton, 2006; Pepper et al., 2017). These figures are representative of all types of impaction but disguises the reality as approximately 91% of Md2M DCC primarily affects patients with MAMd3M and the remaining 9% with HORZMd3M (McArdle et al., 2018). By including patients with other types of Md3M impactions that are not associated with Md2M DCC, its prevalence and clinical significance is underestimated. Justifying widespread prophylactic removal of *all* Md3M based upon the apparent small proportion of patients (14% of all Md3M) who actually succumbed to Md2M DCC would therefore be inappropriate. However, with 44% of all MAMd3M, and 65% in patients over 30 years of age being removed due to Md2M DCC then debate is needed for early intervention in those patients with MAMd3M. In terms of HORZMd3M, the potential for Md2M DCC is still apparent, albeit with a relatively uniform age related prevalence.

In most Md3M disease, the principal disease that indicates the removal will specifically affect the third molar. In such cases leaving the third molar until disease occurs may be appropriate but where long-term retention of the Md3M has significant detrimental effects on the other important dental tissues, in this case the Md2M, then consideration needs to be given in the prevention of DCC forming if there is a significant likelihood of it. Watchful waiting and radiographic observation are pointless as when the disease has occurred, the opportunity to prevent Md2M DCC has been lost (McArdle, 2013; McArdle et al., 2016).

It is apparent that with an ever-increasing frequency of Md2M DCC in older patients that all Md2M with an associated MAMd3M or HORZMd3M are at risk of DCC. If the potential for this disease to occur is significant then it re-opens the debate for early intervention and the prophylactic removal of impacted Md3M; in particular, the MAMd3M.

The results of this study suggest that the ability to qualify and quantify the relative risks of Md2M DCC for patients is becoming more predictable. NICE relies upon outcomes of RCTs to determine policy however this level of evidence cannot exist to support nor refute prophylactic Md3M removal as the use of RCTs in measuring the outcome of Md3M retention would be unfeasible and unethical (Ghaeminia et al., 2016; NICE, 2000; Song et al., 2000). Consequently, there is a lack of acceptable evidence to NICE that offers any support for or against prophylactic removal. Case series studies such as these are often discarded due to potential bias however they are the best evidence available and should not be considered as bad evidence.

NICE's guidance advises against the removal of disease free impacted third molars stating that there is no reliable evidence to support any health benefit. (NICE, 2000) It is apparent that the available evidence suggests that there is an oral health detriment associated with the retention of MAMd3M in particular and the formation of Md2M DCC. With such a detriment outcome as this then the decision to be made is to either accept the potential and deal with it when it occurs or intervene before it is realised.

Md2M DCC is a significant oral health impairment due to a retained MAMd3M and with its development resulting in the loss of 40% of Md2M is significant (McArdle et al., 2016). Early intervention may involve removal of the third molar or where risk of inferior dental nerve injury is apparent consideration may be given to prophylactic coronectomy, or no treatment at all.

4.6 Conclusion

NICE's policy has resulted in patients who require third molar removal becoming older, on average, than previously reported. The number of patients requiring third molar removal has increased beyond the levels pre-NICE and, moreover, the spectrum and frequency of Md3M disease has also changed with Md3M caries and Md2M DCC becoming a more frequently reported finding (Adeyemo et al., 2008; McArdle et al., 2018; McArdle and Renton, 2012; Toedtling et al., 2016).

Md2M DCC has become the most common indication for the removal of partially erupted MAMd3M (McArdle et al., 2018). It is a disease mainly of patients over the age of 30 years. All patients with partially erupted MAMd3M and HORZMd3M are susceptible to Md2M DCC and patients should not be presumed to be at negligible risk. Due to the nature of dental caries, Md2M DCC will take a lengthened period to develop after failed eruption of the MAMd3M. During this period a significant proportion of MAMd3M will succumb to pericoronitis before Md2M DCC can form. However, for those MAMd3M that are retained into later life the likelihood is that they will be removed due to Md2M DCC. Md2M DCC is preventable if the MAMd3M is removed before Md2M DCC becomes established. In terms of the HORZMd3M, the frequency appears to remain constant in older age groups but the number of patients and HORZMd3M assessed was a relatively small proportion of the total number of patients included in the study.

The evidence suggests that all patients with an asymptomatic partially erupted MAMd3M or HORZMd3M are informed of the relative risks related to the long-term retention of their impacted third molars and that consideration is given to early, prophylactic removal of the MAMd3M where appropriate.

Chapter 5

Characteristics of mandibular third molars associated with mandibular second molar distal cervical caries.

Aspects of this chapter were published as:

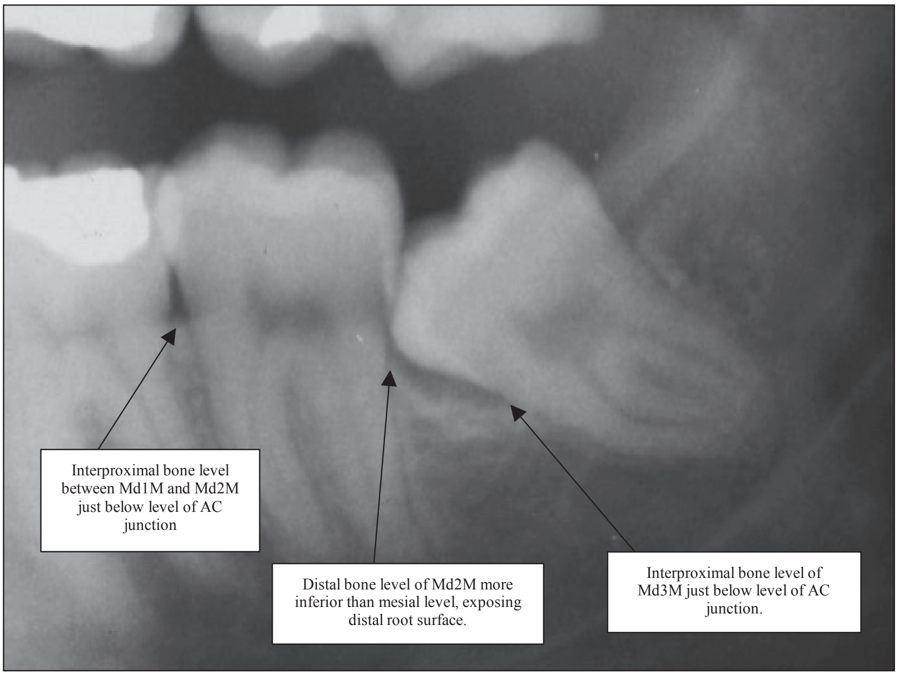
McArdle LW, McDonald F, Jones J. **Distal cervical caries in the mandibular second molar: and indication for the prophylactic removal of the third molar? Update.** British Journal of Oral and Maxillofacial Surgery. 2014; **52**: 185-189.

5.1 Introduction

The established definition of Md2M DCC is a carious lesion which forms on the distal cervical root surface of the second molar which can then progress through the structure of the tooth and eventually invade the pulp chamber with consequent dental abscess formation (McArdle and Renton, 2006; Oderinu et al., 2012). It is typically seen in association with MAMd3M teeth that impact against the distal aspect of the Md2M but is also seen with horizontal impactions to a lesser extent. The impaction of the MAMd3M against the Md2M results in two contributory factors to the development of DCC in the Md2M.

In the normal anatomical relationship, the interproximal alveolar septal bone between two adjacent teeth should be found just below the amelo-cemental junction of each tooth. Generally, the amelo-cemental junction of adjacent teeth will be at the same vertical height as each other resulting in the interproximal bone forming a vertical pillar to the level commensurate with the amelo-cemental junction (Figure 5.1). However, mesial and horizontal impactions of Md3M disrupts this relationship resulting in the mesial amelo-cemental junction of the Md3M sitting at a more inferior vertical level than the second molar's. The interproximal bone cannot maintain its normal interproximal relationship and anatomically has to adapt between the two teeth. This consequently results in the bone settling at a lower level on the distal Md2M root surface to accommodate the mesial amelo-cemental junction of the Md3M at a lower vertical plane. Consequently, the aberrant relationship between the two teeth results in a deficient gingival collar around the distal aspect of the Md2M which, in turn, results in the exposure of the distal root surface of the Md2M to the oral environment.

Figure 5.1. Relationship between interproximal alveolar bone to amelocemental junction of teeth.



Legend: *This image highlights the normal interproximal bone level between the first and the second molar and the irregular interproximal bone level between the second and the third molar. Note the reduced bone level distal to the second molar resulting in exposure of its distal root surface. The bone level around the mesial aspect of the third molar is at its amelocemental junction.*

Secondly, the anatomical relationship of the two teeth creates a location that is difficult to clean with the resultant preferential risk of formation of cariogenic bacterial plaque in the interproximal space. The exposed cementum and dentine of the distal root surface of the Md2M is less resistant to the effects of cariogenic plaque acid than enamel which causes caries to form on the exposed distal root surface of the Md2M. The presence of DCC on the Md2M necessitates the removal of the third molar tooth to facilitate the restoration of the second molar. In certain cases, however, the second molar may be unrestorable and extraction of this tooth may also be indicated. Impacted, partially erupted MAMd3M that contact the second molar in the region of the amelo-cemental junction, place the Md2M at risk of developing DCC (FDSRCS(Eng), 1997; Knutsson et al., 1996; McArdle and Renton, 2006; van der Linden et al., 1995).

In relation to disease associated with impacted third molar teeth, Md2M DCC occurs later in life compared with pericoronitis and is a consequence and complication of retention of an impacted Md3M tooth (McArdle and Renton, 2006; Falci et al., 2012; Chang et al., 2009; Ozec et al., 2009). It has not been seen in the absence of an impacted third molar tooth and has not been seen with other impactions such as vertical, disto-angular or ectopic impactions. Md2M DCC is seen primarily in patients with retained MAMd3M teeth and accounts for the majority of all cases of Md2M DCC with HORIZMd3M accounting for a small proportion (McArdle and Renton, 2006; McArdle et al., 2014; McArdle et al., 2018).

In 2006, the salient features of patients with DCC in the second molar due to the presence of a mesio-angular impacted third molar were defined (McArdle and Renton, 2006). The main characteristics of these patients were that they tended to be 5-years older than the average age of patients undergoing third molar removal and that they had better dental health than the average for grouped age cohorts compared with the 1998 ADHS (McArdle and Renton, 2006). It was suggested that patients presenting with Md2M DCC did so because they had not experienced any significant Md3M disease, such as pericoronitis, earlier in life that would have indicated the removal of the Md3M. Consequently, the retention of the Md3M preserves the unfavourable local anatomical environment which facilitates the formation of Md2M DCC.

5.1.1 Aims

As part of this thesis a cohort of patients with Md2M DCC was collated over a 2-year period (*cohort 2013*) and was compared with the results from a previous preliminary cohort of patients from an earlier study in 2005 (*cohort 2005)* (McArdle and Renton, 2006). The evaluation and comparison of *'cohort 13'* of patients with *'cohort 2005'* was reported in 2014 (McArdle et al., 2014). This paper corroborated the findings from McArdle (2006) in that patients with Md2M DCC tended to be older, had better dental health and that Md2M DCC was associated primarily with a MAMd3M (McArdle et al., 2014; McArdle and Renton, 2006).

This aim of this chapter was to assess the characteristics of patients from 'cohort 13' with a third cohort of patients with Md2M DCC (*'cohort 15'*) identified from the master database of 1011 patients who had Md3M removed.

5.1.2 Ethics

The local ethics committee of KCL Dental Institute was approached for advice regarding the need for ethical approval and as data collection would neither identify individual patients nor influence treatment or outcomes, formal ethical approval was not required.

5.1.3 Methodology

Two cohorts of patients (*'2013' and '2015'*) who had Md3M teeth removed due to Md2M DCC were collated and evaluated over two individual and separate time periods, then compared with each other and subsequently combined together to form a single cohort.

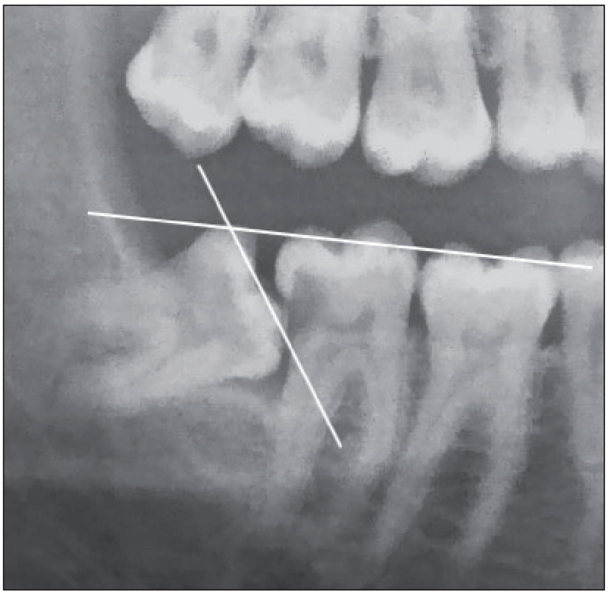
For *'cohort 2013'*, 239 patients who had Md3M removed due to Md2M DCC were evaluated. Data were prospectively collected over a 24month period independently and prior to the collation of the master database of patients. The variables recorded were; age, gender, eruption status of the Md3M, DMFT score and Md3M angulation. Data was recorded directly onto an Excel spreadsheet on a smartphone then analysed.

Patients included in *'Cohort 2015'* were identified from those patients in the master database of 1011 patients assessed for Md3M removal. From this, 163 patients were identified who had had Md3M removed due to Md2M DCC. Data was originally collected prospectively over a 24 month period. The variables recorded were; age, gender; eruption status of the Md3M, DMFT score and Md3M angulation.

DMFT score was used as a basic measure of dental health as it is easily calculated with direct reference to the patient and relevant radiographs. In the calculation of DMFT, all teeth demonstrating dental decay, a dental restoration, or if the tooth was missing were included in the total, however the Md2M was excluded from the calculation if DCC was the only lesion associated with the tooth. The rationale behind this was identify patients whose DMFT would otherwise have been zero and that the DCC would not have otherwise formed had it not been for the influence of the impacted Md3M.

For *cohort 2013*, the mesial angulation of the third molar tooth was calculated by measuring the angle of intersection between the mandibular occlusal plane and the occlusal plane of the third molar: this angle being synonymous with the mesial inclination of the third molar relative to the vertical plane of the second molar (Figure 5.2) (McArdle and Renton, 2006). For *'cohort 15',* the angulation was defined empirically as either mesio-angular or horizontal (see chapter 3, Figure 3.1).

Figure 5.2 Calculating mesial angulation of the Md3M for *'cohort 13'*.



Legend: *This image demonstrates the method of calculating the mesial inclination of the Md3M for 'cohort 13'. The angle of intersection of the mandibular occlusal plane and the occlusal plane of the Md3M is equal to the mesial inclination of the Md3M relative to the vertical inclination of the Md2M. The method of calculating the angle of impaction is analogous with that shown in figure 3.1.*

5.1.2 Statistical analysis.

The sample and outcome characteristics were summarised using descriptive statistics. Sample means, number, range and standard deviation of age were calculated for each cohort. Sample means, number, range and standard deviation were calculated for DMFT for age matched groups. The mean age of the two cohort groups presenting with Md2M DCC were compared using one way ANOVA. In addition, the mean DMFT was compared with the 2009 ADHS for significance using one way ANOVA. The comparison of Md2M with DCC, and the Md3M angulations of impaction were carried out using Z test for proportions Statistical significance was assumed at 5%

level and the analyses were carried out using SPSS version 23.0 and MedCalc online software.

5.2 Results *'cohort 2013'*

For *'cohort 2013',* there were 239 patients in total, 143 males and 96 females (60:40, M:F ratio). A total of 288 Md3Ms were extracted due to DCC in the Md2M. 190 had DCC in a single Md2M and 49 had DCC in both Md2Ms (bilateral disease). There were 144 left-sided Md3M and 144 right-sided Md3M removed.

The mean age of this group of patients was 32.1 years (range 20-65 years, SD 7.85 years). Dental health was measured by calculating the compensated DMFT score (decayed, missing or filled teeth): 161(67%) patients had a DMFT score of 5 or less; 56 (23%) between 6-10, and 22 (9%) patients with a DMFT score of 11 or more. Of note, 50 (21%) patients had a compensated DMFT score of 0 (zero) where the only carious lesion was the DCC lesion associated with the second molar tooth. For patients aged 15-24 years, the mean DMFT was 2.6 (SD 3.5, n=24); for patients aged 25-34 years, the mean DMFT was 3.6 (SD 3.7, n=143); for patients aged 35-44 years, the mean DMFT was 5.9 (SD 4.9, n=49); for patients 45-54 years, the mean DMFT was 6.4 (SD 4.5, n=20); and for 55-64 years the mean DMFT was 6 (SD 3.7, n=3) (Figure 5.3).

Clinically all 288 Md3Ms were partially erupted. Radiographic evaluation established that all were in contact with the second molar tooth at, or close to, the amelo-cemental junction and the majority were mesio-angularly impacted against the second molar. Angulations of the third molar were grouped accordingly: 255 (89%) had a mesial angulation of between 40^0 and 80^0, 28 (10%) a mesial angulation less than 40^0, and 5 (1%) greater than 80^0; this latter angulation being essentially horizontal.

5.3 Results *'cohort 2015'*

163 patients who had Md3M due to Md2M DCC were identified from the master database of 1011 Md3M patients. Of these, 102 were males and 61 were females (3:2, M:F ratio). Of these 163 patients, 128 patients had DCC in a single Md2M and 35 had DCC in both Md2Ms (bilateral disease). A total of 198 Md3Ms were extracted due to DCC in the second molar - 97 left-sided and 101 right-sided.

The mean age of this group of patients was 32.7 years (range 21-55 years, SD 7.29 years). Dental health was measured by calculating the compensated DMFT score (decayed, missing or filled teeth): 104 (64%) patients had a DMFT score of 5 or less; 40 (25%) had a DMFT score between 6-10, and 19 (12%) patients with a DMFT score of 11 or more. Of note, 34 (21%) patients had a compensated DMFT score of 0 (zero) where the only carious lesion was the DCC lesion associated with the second molar tooth. For patients aged 15-24 years, the mean DMFT was 3.4 (SD 5.1, n=13); for patients aged 25-34 years, the mean DMFT was 3.5 (SD 3.5, n=97); for patients aged 35-44 years, the mean DMFT was 6.2 (SD 4.1, n=40); for patients 45-54 years, the mean DMFT was 8.8 (SD 4.6, n=11); and for 55-64 years the mean DMFT was 8 (SD 6, n=2) (Figure 5.3).

Clinically all 198 Md3Ms were partially erupted. Radiographic evaluation established that all were in contact with the second molar tooth at, or close to, the amelo-cemental junction. 180 (90%) Md3M were classified as mesio-angularly impacted against the second molar and 18 (10%) classified as horizontally impacted.

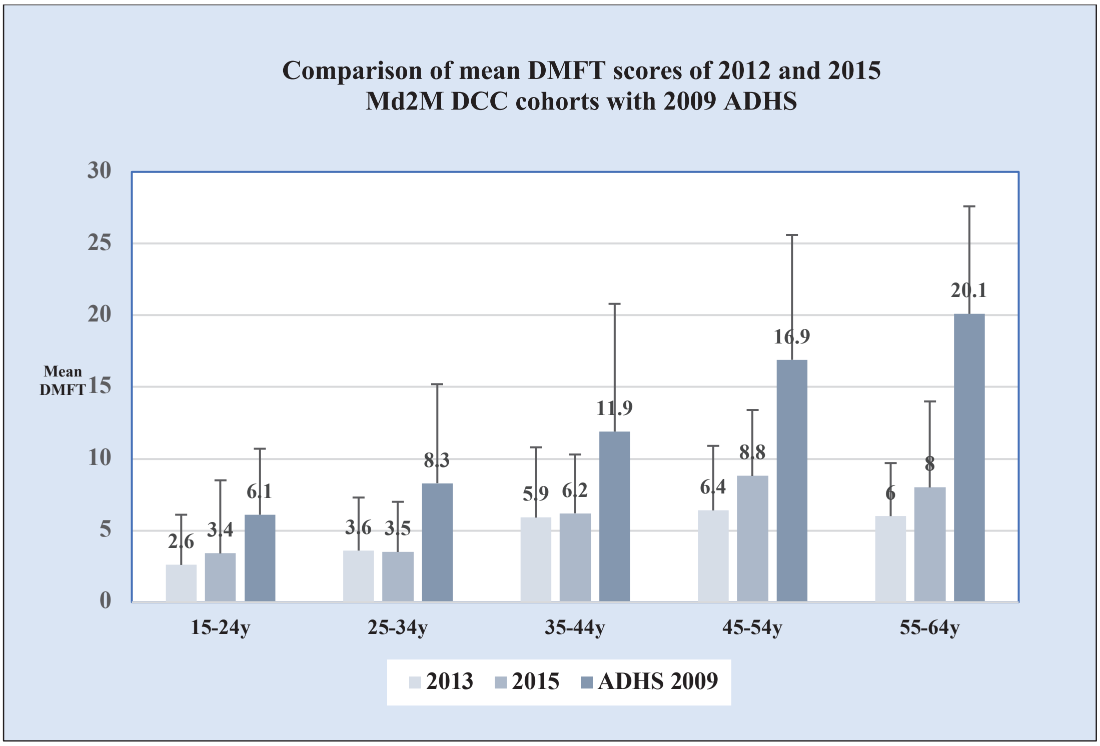
Comparisons of the two groups of patients with Md2M DCC demonstrated a similar profile. The mean age of patients presenting with Md2M DCC was similar 32.2 years and 32.7 years respectively (*one way ANOVA* p=0.4392), with the majority of patients with Md2M DCC associated with a MAMd3M (*comparison of proportion of each cohort with MAMd3M associated with Md2M DCC* p=0.0393). DMFT scores of both cohorts were compared with each other and with the 2009 Adult Dental Health Survey (Figure 5.3).

The Adult Dental Health Survey of 2009 published data on the average number of sound, unrestored teeth of patients within given age groups, whereas previous Adult Dental Health Surveys had published the average DMFT scores for patients (ADHS, 2000; ADHS 2011). Email communication with the Office of National Statistics and the authors of the 2009 ADHS confirmed that the calculation of average DMFT scores based on the results of the 2009 ADHS could be calculated by subtraction of the average value for sound, unrestored teeth from 32; the number of teeth within a fully dentate individual (Triffit, 2012). Variability exist with the calculation of DMFT scores as some authors either exclude or include third molars from the calculation of

DMFT. Agenesis of third molars is commonplace and their inclusion in calculating DMFT can result in potential overestimation and bias. DMFT scores for each of the 2013 and 2015 cohorts were calculated excluding the third molars. The ADHS 2009 report does not report the standard deviation associated with the calculation of the sound teeth but does calculate standard error. Standard deviation can be calculated by multiplying the standard error by the square root of the population number (ADHS, 2011). The DMFT values as calculated from the ADHS 2009 confirmed that for patients aged 15-24 years, the mean DMFT was 6.1(SD 4.6, n=650); for patients aged 25-34 years, the mean DMFT was 8.3 (SD 6.9, n=910); for patients aged 35-44 years, the mean DMFT was 11.9 (SD 8.9, n=1280); for patients 45-54 years, the mean DMFT was 16.9 (SD 8.7, n=1200); and for 55-64 years the mean DMFT was 20.1 (SD 7.5, n=1160).

Data from the 2009 ADHS reports age in cohorts of 10 years. The mean DMFT of patients from each cohort was calculated for similar age ranges to allow comparison with the 2009 ADHS. The mean DMFT scores for each of the two Md2M DCC cohorts were comparable with each other and both were approximately 50% less than the comparable age cohorts for the 2009 ADHS (Figure 5.4) (ADHS, 2011).

Figure 5.3. Comparison of mean DMFT scores of each Md2M DCC cohort with the ADHS 2009.

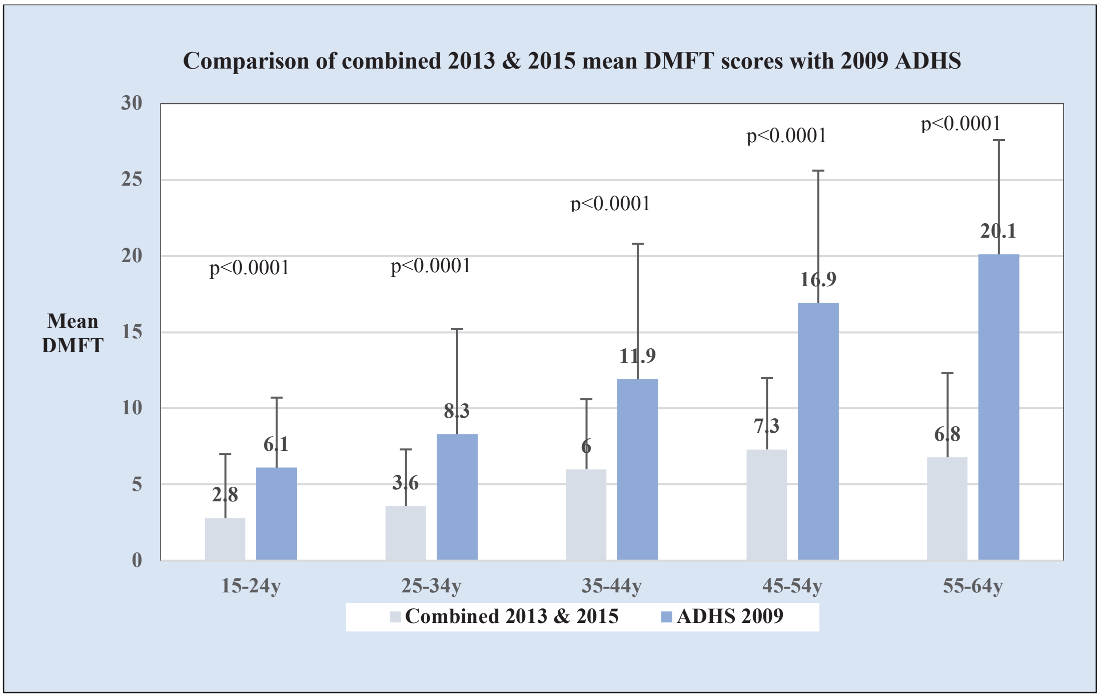


Legend: *This graph illustrates the mean DMFT scores of patients in each of the two Md2M DCC cohorts (2013 and 2015) compared with the 2009 ADHS. It can be seen that the mean DMFT of each of the Md2M DCC cohorts are comparable with each other and are approximately 50% less than the mean DMFT scores of comparable aged patient cohorts from the 2009 ADHS. (Standard Deviation bars illustrated for mean DMFT, see text for values).*

5.4 Combined cohorts 2013 and 2015.

Both cohorts of patients with Md2M DCC were combined to create a pooled cohort of 402 patients collected over a 4 year period: 245 males and 157 females (6:4, M:F ratio) having a total of 486 Md3M removed due to Md2M DCC. 318 patients had a single Md3M removed due to Md2M DCC and 84 patients had bilateral Md2M DCC requiring the removal of a further 168 Md3M. A total of 463 Md3M were mesio-angular impacted (95%) and 23 Md3M were horizontally impacted (5%). The combined mean age was 32.4 years (range 20-64 years, SD 7.64 years) and the combined cohort's mean DMFT scores were calculated based on 10 year age ranges for comparison with the 2009 ADHS. For patients aged 15-24 years, the mean DMFT was 2.8 (SD 4.2, n=37); for patients aged 25-34 years, the mean DMFT was 3.6 (SD 3.7, n=240); for patients aged 35-44 years, the mean DMFT was 6 (SD 4.6, n=89); for patients 45-54 years, the mean DMFT was 6 (SD 4.6, n=31); and for 55-64 years the mean DMFT was 6.8 (SD 5.5, n=4) (Figure 5.4).

Figure 5.4 Comparison of combined 2013 & 2015 DMFT scores with ADHS 2009.



Legend: *This graph illustrates the mean DMFT of the combined Md2M DCC cohorts (2013 and 2015) – total of 402 patients, compared with the 2009 ADHS. It can be seen that the mean combined DMFT of both the Md2M DCC cohorts are approximately 50% less than the mean DMFT scores of comparable aged patient cohorts from the 2009 ADHS, (p<0.0001). Suggesting that patients with Md2M DCC have better dental health than average. (Standard Deviation bars illustrated for mean DMFT, see text for values).*

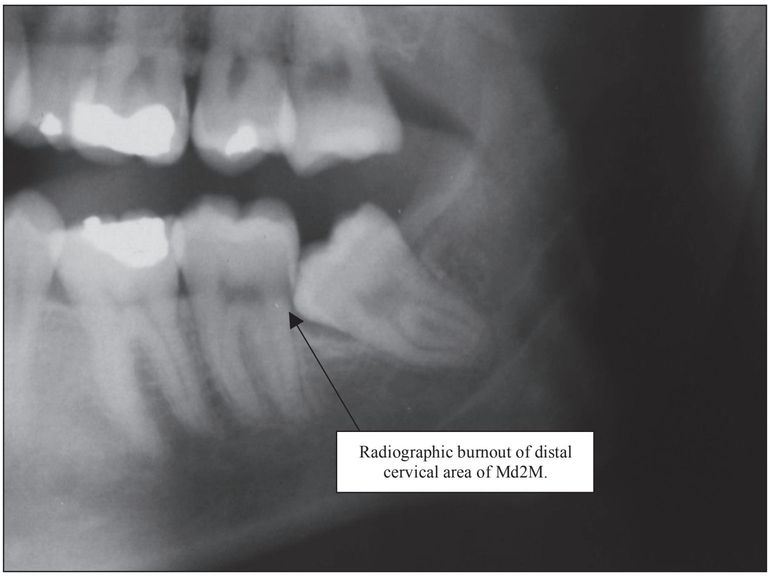
5.5 Discussion

Distal cervical caries in the Md2M has not been reported in isolation without the influence of an impacted Md3M tooth (McArdle, 2014). DCC is not, however, exclusive to the Md2M. DCC has been observed on the distal root surface of maxillary second molar teeth (Mx2M) in association with mesial impacted maxillary third molar teeth MAMx3M that are partially erupted. Variants of DCC also exist with other teeth were impaction of a tooth causes exposure of the root surface of adjacent teeth. Examples of this can be seen with the lingual or palatal impaction of second pre-molar teeth and the resultant root exposure of the adjacent first premolar and molar teeth.

Md2M DCC is not seen in isolation. It does not form in the absence of an impacted Md3M tooth. Although caries is caused by demineralisation of the dental hard tissues by acid production from bacterial plaque, it is the impaction of the Md3M which creates a local site unamenable to adequate oral hygiene with resultant bacterial plaque accumulation and consequent insult to the distal root surface of the Md2M.

Although caries can form on the distal aspect of any tooth, DCC is distinct in that its location is observed at the amelo-cemental junction of the tooth. It is essentially distal root caries brought about by the exposure of the distal root surface due to the impaction of the Md3M and the inaccessibility for oral hygiene. Md2M DCC is unique and does not develop in the absence of the impacted third molar. Concern has been raised that in other studies, radiographic cervical burnout artefact may be misdiagnosed as DCC resulting in a higher reported incidence (Allen et al., 2009; Littler, 1997). For this thesis' databases, patients whose radiographic images suggested cervical burnout artefact were excluded as a diagnosis of Md2M DCC (Figure 5.5). Removal of such teeth may still have been undertaken either due to other concomitant clinical indications or when patients elected to have their third molar removed to eliminate the risk of Md2M DCC from forming.

Figure 5.5. **MAMd3M with radiographic burnout of the distal cervical area of the Md2M.**



Legend: *This figure demonstrates an impacted MAMd3M associated with a Md2M that has radiographic burnout of the distal cervical area, with the potential to be misinterpreted as Md2M DCC.*

5.5.1 Md3M Angulation.

The angulation of the third molar is a significant factor associated with the risk of developing DCC in the second molar. This type of second molar caries is seen primarily in association with mesio-angular impacted third molars and, as corroborated by other studies, a mesial angulation, is the most common (Allen et al., 2009; Chang et al., 2009; Falci et al., 2012; McArdle and Renton, 2006; Oderinu, et al., 2012; Ozeç et al., 2009). The combined cohorts of patients with Md2M DCC accounted for a total of 486 Md3Ms extracted; 463 (95%) of these had a mesial angulation and 23 (5%) had a horizontal angulation. These features concur with other authors published work however some authors have documented Md2M DCC in conjunction with vertical and disto-angular impactions (Allen et al., 2009; Chang et al., 2009; Falci et al., 2012; Oderinu et al., 2012; Ozeç et al., 2009; Syed et al., 2017; Toedtling et al., 2016). Toetdling (2016) identified patients with other angles of impaction, such as vertical impactions, with distal caries on the Md2M (Toedtling et al., 2016). Teotdling's study, however, included patients with both Md2M DCC and with interproximal caries between the Md2M and the Md3M. Toetdling incorporated these together and described the condition as distal surface caries (DSC), however, whereas Md2M DCC is exclusive to the Md2M and impacted Md3M, interproximal caries is not. Interproximal caries can be seen in relation to any two teeth with a proximal enamel contact. Syed et al, (2017) also reported on 979 patients' OPGs with impacted Md3M teeth and noted that 39% of patients displayed radiographic evidence of distal caries on the Md2M (Syed et al., 2017). Impacted MAMd3M accounted for 60% of patients with Md2M distal caries, with 24% horizontal, 11% vertical, and 3% disto-angular impactions. In addition, Falci (2012) reported that DCC was seen in vertical impactions in addition to both mesial and horizontal impactions (Falci et al., 2012). It is not evident whether any these studies differentiated between DCC and interproximal caries as separate entities or combined them in the manner of Toetdling. These published papers, unfortunately, only demonstrate clinical images of Md2M DCC with MAMd3M but no images of Md2M DCC with vertical or disto-angular Md3M. In one other study by Raheem (2015) demonstrated HORIZMd3M to be the most common impaction related to Md2M distal caries however numbers of radiographs investigated were small (Raheem, 2015). None the less the MAMd3M is by far the most commonly reported type of impaction related to the formation of Md2M DCC.

5.5.2 Male:Female ratio

Both 2013 and 2015 cohorts demonstrated a comparable male:female ratio of approximately 3:2 and other studies of Md2M DCC have generally reported a similar ratio and predilection towards male predominance (Silva et al., 2015; Syed et al., 2017). From the master database of all indications for Md3M removal the ratio of male to female demonstrates a reverse predominance of females to male of 3:2. Other studies of third molar removal also demonstrate a predominant ratio of female to male (Knutsson et al., 1996; Liedholm et al., 1999). The reason why more males appear to be affected by Md2M DCC may be speculative and more complex to translate. From the master Md3M database the mean age of patients presenting for Md3M removal is 32.4 years, however the mean age of males presenting is 35.2 years and for females it is 31 years. In general, females do have a tendency to interact with health professionals early, whereas, males have a tendency to delay interaction with medical professionals regarding health issues. Pericoronitis is a disease which presents early for patients and mild symptoms may make females more likely to interact early with dentists than males. Consequently, as demonstrated by the mean ages of male and female patients, removal may be undertaken at an earlier age for females before patients can develop

Md2M DCC. Males tendency to delay or avoid presentation may disadvantage them in that they appear to retain their Md3M and are older when they present and more likely that Md2M DCC will be their diagnosis.

5.5.3 DMFT scores

Both the 2013 and the 2015 cohorts of patients had comparable mean DMFT scores for each age group. When compared independently and collectively with the 2009 Adult Dental Health Survey, the mean DMFT score for patients with DCC was approximately 50% less than the mean score for comparable age groups in the general population (Figures 5.3 and 5.4 p<0.0001). (ADHS, 2011) This corresponds to a previous study in 2005, that was based on the 1998 ADHS in which the mean DMFT was also approximately 50% less than comparable age groups (ADHS, 2000; McArdle and Renton, 2006).

This data suggests that patients with better dental health, as measured by DMFT score, will possibly retain a partially erupted third molar later into life and, in the case of MAMd3M or HORIZMd3M, risk the development of Md2M DCC (McArdle and Renton, 2006). It also contradicts the notion that susceptibility to Md2M DCC is solely associated with an increased susceptibility to dental caries (FDSRCS(Eng), 1997; Knutsson et al., 1996; van der Linden et al., 1995). It would be logical to assume that people with low DMFT scores have a good standard of oral hygiene that contributes to oral hygiene maintenance of the coronal aspect of the partially erupted third molar thus minimising the likelihood of pericoronitis occurring. Minimising the potential for pericoronitis would likely result in the longer term retention of the third molar. Moreover, in the case of a MAMd3M, with exposure of the distal cervical root of the second molar to the oral environment, DCC would be one potential outcome. DCC, however, appears to develop in older patients and this may be may be reflected in the latent time period that it takes for dental caries to form compared to the development of pericoronitis post-eruption of the third molar (McArdle et al., 2018; McArdle and Renton, 2006; McArdle and Renton, 2012).

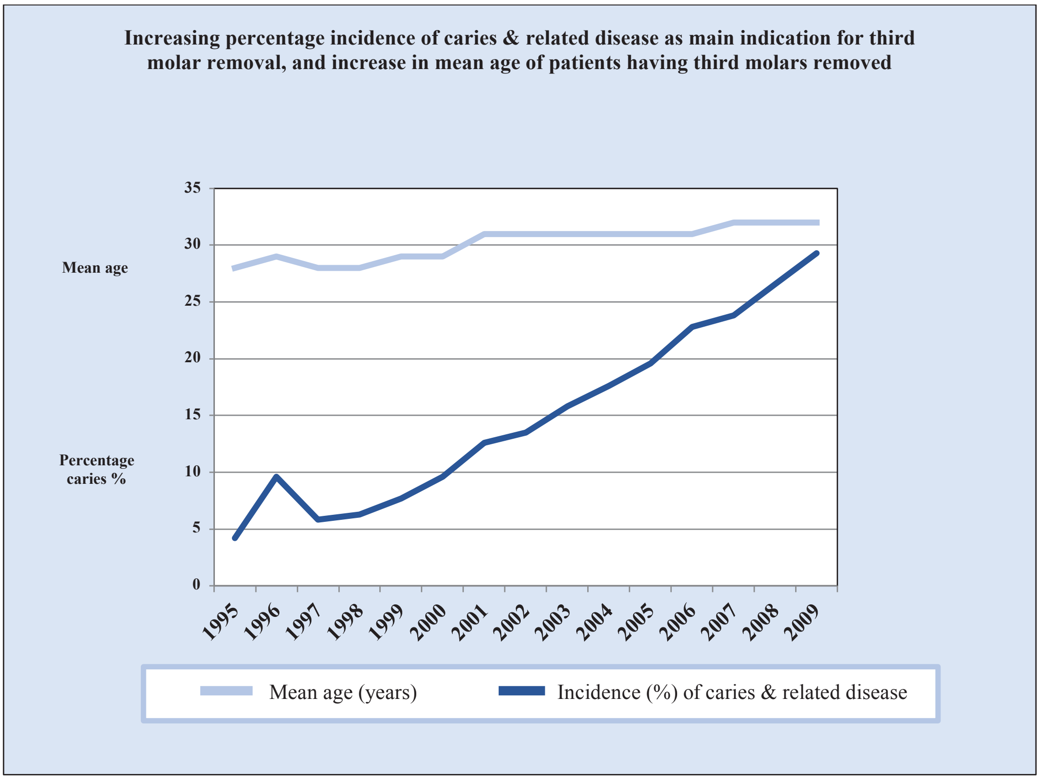
The significance of better dental health and its association with Md2M DCC and an impacted Md3M may be explained by the general improvement in dental health over the last 40 years. Shepherd (1994a) speculated that there would be an increase in the number of patients requiring Md3M removal in the latter half of the 20^{th} century and beyond as the influence of better dental health and well-being becomes established (Shepherd, 1993; Shepherd, 1994a). Dental health prior to the 1970/80s was generally poor, however, with the introduction of fluoride dentifrice, better dental attendance and an improved attitude to dental health, patients and the professions attitude to patients resulted in less teeth being extracted. The early extraction of permanent first molar teeth in children was common and resulted in consequent mesial drift of the second molar which in turn gave space for the unhindered eruption of the third molar. As a more conservative approach became established, the restoration and retention of molar segments became the norm which in turn will have increased the rate of impacted of Md3M teeth (Shepherd, 1993; Shepherd, 1994a).

5.5.4 Mean age

The mean age of patients presenting with Md2M DCC is 32.4 years and is equivalent to the mean age of patients having Md3M removed as calculated from the master database and from HES data of patients having third molar surgery in the UK: 32 years (HES, 2018; McArdle et al., 2018; McArdle and Renton, 2012). It had previously been suggested that the average age of patients with Md2M DCC tended to be 5 years older than average compared with the mean age all patients undergoing third molar removal. This observation was made from comparison with third molar removal in the mid 1990's and reflected studies that included a significant proportion of patients who had prophylactic third molars removed in a younger age group (Brickley et al., 1996; de Boer et al., 1995; Nordenram, et al., 1987). In the UK, the mean age of patients undergoing third molar removal in the early 1990s was 25 years, however, the mean age of third molar patients has steadily increased over the last 30 years and is now 32 years (HES, 2018; McArdle et al., 2018; McArdle and Renton, 2012). The mean age of all patients has increased primarily due to the introduction of third molar clinical guidance by NICE and other stakeholders, such as the Royal College of Surgeons', and the consequent change of professional dogma. Such guidance has resulted in a change of practice which has shifted away from prophylactic removal of third molars, primarily in younger patients, to removal based on definitive clinical indications resulting in the upward change in mean age (NHS Centre for Reviews and dissemination, 1998; McArdle and Renton, 2012; Mettes et al., 2012; SIGN, 2000; NICE, 2000).

Previously reported data suggests that there is a relationship between the increase in the mean age of patients and an increase in the incidence of all third molar related caries. As has been discussed in previous chapters, data collection by the NHS HES agency does not filter data to allow isolation of caries solely affecting the third molar or Md2M DCC attributable to the Md3M DCC. Nonetheless, over the last 30 years, as patients have become, on average, older; there has been an increase in the reported incidence of caries and related disease, from approximately 7% to 30%: (Figure 5.6) (HES, 2018; McArdle and Renton, 2012).

Figure 5.6 Percentage incidence of caries & related disease as main indication for third molar removal and mean age increase of patients having third molar teeth removed.



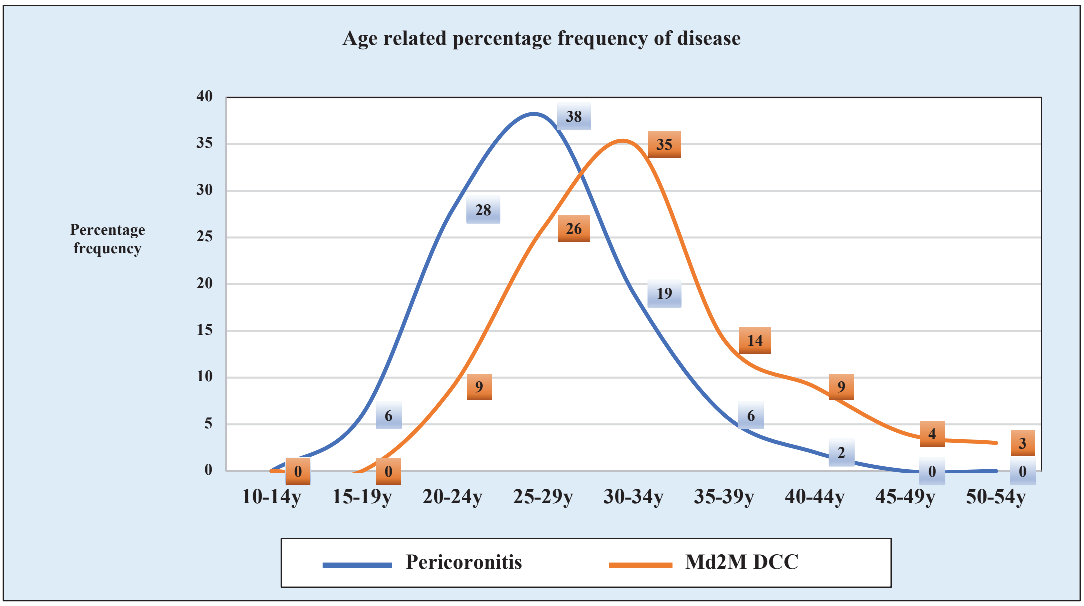
Legend: *Based solely on HES data from 1995 to 2009, this graph illustrates the increasing annual percentage in caries related disease as the primary indication for third molar removal compared with the annual increase in the mean age of patients. As the mean age of patients has increased from 28 in 1995, to 32 in 2009 there has been a corresponding increase in caries related disease from approximately 7% to 30% over the corresponding period.*

The mean age of this combined cohort of 402 patients with Md2M DCC (32.4 years) suggests a similar relationship between increased mean age and the overall increase in incidence of third molar related caries and an increasing incidence of DCC in older patients (Bruce et al., 1980; McArdle and Renton, 2012). It has been demonstrated that third molar caries & related disease accounts for 27% of all Md3M removed, which also re-enforces and corroborates the general increasing trend of third molar related caries as suggested by HES and previously reported (HES, 2018; McArdle et al., 2018; McArdle and Renton, 2012).

Data from the thesis' main database and reported in 2018, demonstrates that the mean age of patients having Md3M removed due to pericoronitis is 27.5 years, 5 years younger than average for all patients having Md3M removed (32.4 years) (McArdle et al., 2018). Pericoronitis is still the main clinical indication for Md3M removal and accounts for 49% of all Md3M removed and is the major indication for Md3M removal in all angles of Md3M impaction apart from MAMd3M where Md2M DCC is the major indicator for removal. Pericoronitis accounts for only 32% of MAMd3M removed but Md2M DCC accounts for 44% (McArdle et al., 2018).

Whereas the mean age of all patients has increased, the mean age of patients, based on disease, varies as discussed in chapter 3. Patients requiring Md3M removal due to Md2M DCC are still 5 years older than patients with pericoronitis affecting Md3M teeth requiring removal. Also noteworthy is that the peak percentage frequency of both pericoronitis and Md2M DCC is separated by a similar 5 year margin with patients between the ages of 25-29 year accounting for 38% of all Md3M removed due to pericoronitis (n=698) whereas the peak incidence for Md3M removal due to Md2M DCC is in the 30-34 year age group account for 35% (n=198) (Figure 5.7).

Figure 5.7. Comparison of the percentage frequency of Md2M DCC and Pericoronitis from master database.



Legend: *This graph illustrates the percentage frequency of Md2M DCC and Pericoronitis based on 5 year age cohorts. The peak frequency of pericoronitis occurs between the ages of 25-29 years of age accounting for 38% of all Md3M removed due to pericoronitis. The peak frequency of Md2M disease occurs between the ages of 30-34 years accounting for 35% of all Md3M removed due to Md2M DCC. N=698 Md3M removed due to pericoronitis and N=198 Md3M removed due to Md2M DCC.*

The occurrence of DCC in the mandibular second molar in association with impacted third molars has become more widely reported and is not isolated to any specific racial group (Chang et al., 2009; Falci et al., 2012; Oderinu et al., 2012; Ozeç et al., 2009; Raheem et al., 2015; Silva et al., 2015; Syed et al., 2017; Toedtling et al., 2016). These more recent studies have reported the incidence of DCC to be up to 20% in patients having third molars assessed, with some reporting an incidence of approximately 40% in MAMd3M (Allen et al., 2009; Chang et al., 2009). Data already published from this research demonstrates that Md2M DCC accounts for 14% of all Md3M removed and, as mentioned, accounts for 44% of all MAMd3M removed (McArdle et al., 2018).

Older studies tend to report a younger mean age in the region of 25 years for patients undergoing third molar removal with pericoronitis being the most common indication for Md3M removal (Brickley et al., 1996; Chiapasco et al., 1993; de Boer et al., 1995;

Lysell, 1988; Nordenram, Hultin et al., 1987). These older studies were published at a time when prophylactic removal in younger patients was common thus biasing towards a younger mean age for third molar removal. In younger patients, caries, as an indication for third molar removal, is relatively low and historically the reported incidence of Md2M DCC in younger patient groups has also been relatively low: 2-5%, if reported at all (Brickley et al., 1996; Bruce et al., 1980; McArdle and Renton, 2006). From the database Md2M DCC is seen infrequently in younger age groups and accounts for 5% of all Md3M removed in the patients under the age of 25 years and 16% in all patients over the age of 25 years.

It can be reasoned that the relative risk of developing DCC on a Md2M is significant with DCC now being responsible for a rising percentage of third molars removed (Allen et al., 2009; Bruce et al., 1980; Chang et al., 2009; Falci et al., 2012; Oderinu et al., 2012; Ozeç et al., 2009; Silva et al., 2015). Pericoronitis though, is still the most common indication for all third molar removal but is diagnosed more frequently in younger patient groups (Brickley et al., 1996; Bruce et al., 1980; Knutsson et al., 1996; Lysell et al., 1988; McArdle et al., 2018; Nordenram et al., 1987; van der Linden et al., 1995). From the main database 65% off all Md3M are removed due to pericoronitis in the under 30s (McArdle et al., 2018). The removal of Md3Ms in younger adults due to pericoronitis removes the main contributing factor for DCC of the Md2M, specifically the MAMd3M. With the third molar absent the local anatomical factors that would contribute to the development of DCC are eliminated thus preventing the opportunity for formation of DCC on the Md2M. If pericoronitis were not such a common feature of third molar disease in younger patients, then the proportion of third molar teeth retained later into life would be greater. As a consequence, it had been suggested that the incidence of DCC of the second molar will rise accordingly as is the case with the frequency of general caries in relation to third molars in older patient groups (Bruce et al., 1980; HES, 2018; McArdle et al., 2018; McArdle and Renton, 2012). As was demonstrated in chapter 4 the frequency of Md2M DCC as the primary indication for the removal of MAMd3M increases with age and now accounts for over 60% of MAMd3M removed in the over 30s (McArdle et al., 2019)

5.6 Conclusion

In summary, the common features of patients requiring Md3M removal due to Md2M DCC are of similar age to all patients having Md3M removed for all indications. However, patients are generally 5 years older, on average, than patients requiring Md3M removal due to pericoronitis which is the most common indication for all Md3M removal. There is a 3:2 predilection for males to present with the condition and the majority (95%) of Md2M DCC cases have an associated impacted MAMd3M as the main contributing factor, with HORIZMd3M responsible for approximately 5%. Patients general dental health as measured by DMFT scores are 50% less than the average for comparable age ranges as compared with the ADHS of 2009. However, patients requiring Md3M removal have better dental health in general when compared with patients from the 2009 ADHS (ADHS, 2011). The frequency of Md2M DCC increases in patients requiring removal of MAMd3M as they age.

Chapter 6

The mesially impacted mandibular third molar: the incidence and consequences of distal cervical caries in the mandibular second molar.

Aspects of this chapter were published as:

McArdle LW, Patel N, Jones J, McDonald F**. The mesially impacted mandibular third molar: the incidence and consequences of distal cervical caries in the mandibular second molar.** The Surgeon. Journal of the Royal Colleges of Surgeons of Edinburgh and Ireland. 2016. **16**(2):67-73.

6.1 Introduction

As has been observed, partially erupted MAMd3M are a causal factor in the development of DCC on Md2M (Allen et al., 2009; Chang et al., 2009; Falci et al., 2012; McArdle and Renton, 2006; McArdle et al., 2014; Oderinu et al., 2012; Ozeç et al 2009). As a consequence of DCC formation, treatment of the Md2M, either in the form of restoration of the Md2M or removal of the Md2M will be indicated. Moreover, the diagnosis of Md2M DCC will require the removal of the Md3M, not only to facilitate the restoration of the second molar but also to eliminate the risk of recurrence of DCC in the second molar.

Although the specific treatment of the second molar will be determined by various clinical and patient factors, the definitive treatment outcomes for patients with Md3M related DCC of the Md2M has not been quantified. This study evaluates the treatment outcomes for Md2M teeth affected by DCC in a cohort of patients who had their Md3M removed as a consequence of DCC and estimates the relative costs of managing this disease.

6.1.1 Aims

The aims of this study were to determine the treatment outcomes of the Md2M for patients affected by Md2M DCC who had Md3M removed due to DCC of the Md2M. In addition, to estimate the number of patients in England who are treated for Md2M DCC on an annual basis and to calculate the relative direct and indirect financial costs of treating Md2M DCC including the costs Md3M removal.

6.1.2 Ethics

The local ethics committee of GSTT NHS Foundation Trust was approached for advice regarding the need for ethical approval and as data collection would neither identify individual patients nor influence treatment or outcomes, formal ethical approval was not required.

6.1.3 Methodology

Data from two previous published studies of patients with DCC in 2006 and 2014 were combined (McArdle and Renton, 2006; McArdle et al., 2014). This data identified a total of 339 patients who had their Md3M removed due to DCC of the Md2M. Of these 339 patients, 121 patients had contemporary contact details. These patients were contacted to ascertain what the treatment outcome was for their Md2M tooth, subsequent to the removal of their third molar tooth: a total of 84 patients responded. Treatment outcomes for the Md2M would either be extraction or restoration of the tooth.

To estimate the total number of patients undergoing third molar removal a number of datasets were accessed. NHS HES datasets for admitted and out-patient procedures were reviewed for 2013/14 (HES, 2018). Procedure codes F0910 and F0930 relate to removal of third molar teeth and collectively identify the estimated total number of patients undergoing a third molar procedure in the NHS. In addition to codes F0910 and F0930, which relate solely to third molar procedures, the procedure code F0920 (removal of impacted tooth) was excluded from the calculation. Code F0920 relates to surgical removal of impacted teeth but is non-specific in identifying which specific impacted tooth was removed. Although the majority of impacted teeth in the dentition are third molars, this code encompasses other impacted teeth such as impacted maxillary canines and impacted premolar teeth as well third molars. For this group, the mean age of patients was 21 years, suggesting that a significant proportion of patients were young and not at an age were third molars would be routinely removed. Consequently, this code was excluded from evaluation, however its exclusion may result in an under estimation of true numbers of third molar removal (HES, 2018).

The total volume of patients having third molar removal in hospital secondary care with all types of anaesthesia was estimated using HES data and the ratio of patients having third molar removal in secondary care from the actual numbers and ratio of patients at Guy’s and St Thomas NHS Foundation Trust Hospital (GSTT) having third molar surgery undertaken in 2014 (GSTT, 2015). HES data only includes patients who have treatment as a day-case procedure under general anaesthesia or sedation as opposed to out-patient procedures under local anaesthesia. The number of day-case and outpatient procedures was calculated from annual recorded data. The ratio of this GSTT data and HES data was used to estimate the total volume of patients having secondary care third molar removal in England on an annual basis.

The volume of patients having Md3M removal in primary care was estimated using the last recorded annual data for Md3M from NHSBSA datasets along with the percentage increase in the number of patients having secondary care third molar removal, as reported in chapter 2, was used to estimate the volume Md3M removed in primary care.

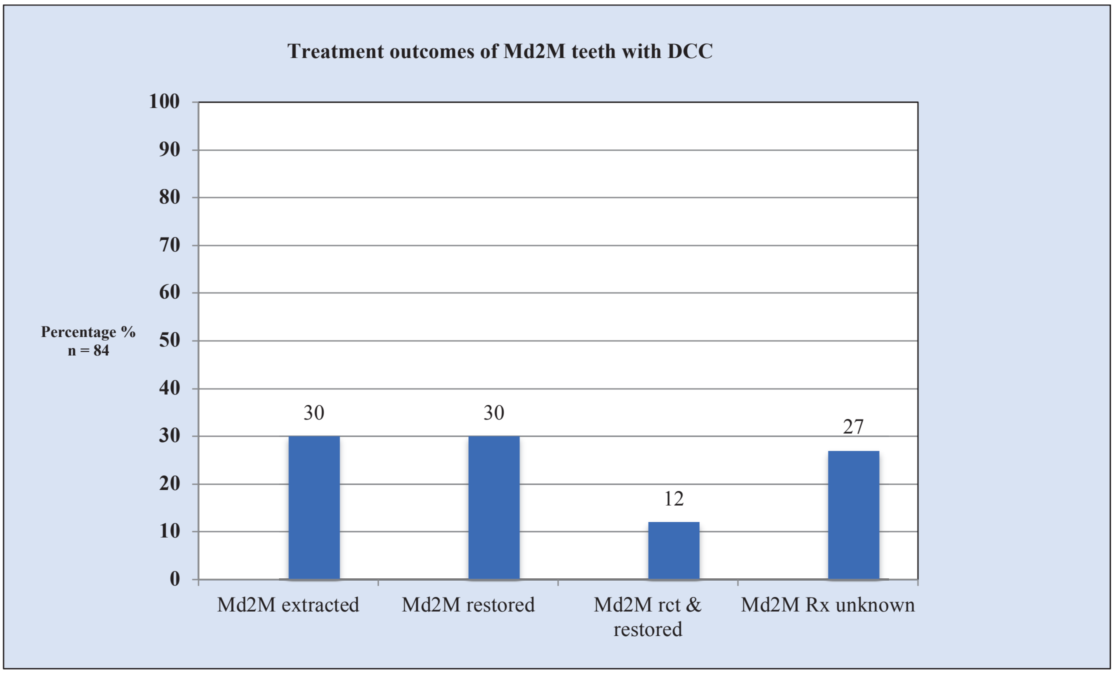
The estimated total volume of patients in England presenting with Md2M DCC and requiring Md3M removal was calculated using these figures along with the percentage frequency of Md2M DCC as reported in chapter 3.

Costs for treatment related to Md3M and Md2M were calculated using NHS national tariffs for primary and secondary care, and indirect costs based on UK national average earnings. NHS costs were based on 2014 figures and were accessed from the online NHS national tariff payment system (NHS, 2014). UK national average earnings were based on 2014 figures of the annual survey of hours and earnings available online from the Office of National Statistics (ONS, 2014a)

6.2 Results

Of the 84 patients, 44 were female and 40 were male. All respondents had had a single Md3M removed due to Md2M DCC. Of these 84 patients, 38 were from the 2006 cohort and 46 from the 2014 cohort. Of the 2006 cohort; 24% of second molar teeth had been extracted, 45% were restored and 31% could not recall what treatment they had. Of the 2014 cohort: 35% had been extracted, 41% were restored and 24% could not recall what treatment they had. In total 26 patients (30%) confirmed that their Md2M had either been extracted at the time of third molar removal or subsequent to third molar removal; 26 patients (30%) confirmed that they had had the second molar tooth restored and that it was still present. A further 10 patients (12%) confirmed that they had endodontic treatment of the second molar prior to restoration of the tooth. 22 patients (27%) could not recall what treatment they had for their second molar and could not confirm if the second molar tooth was present or not (Figure. 6.1).

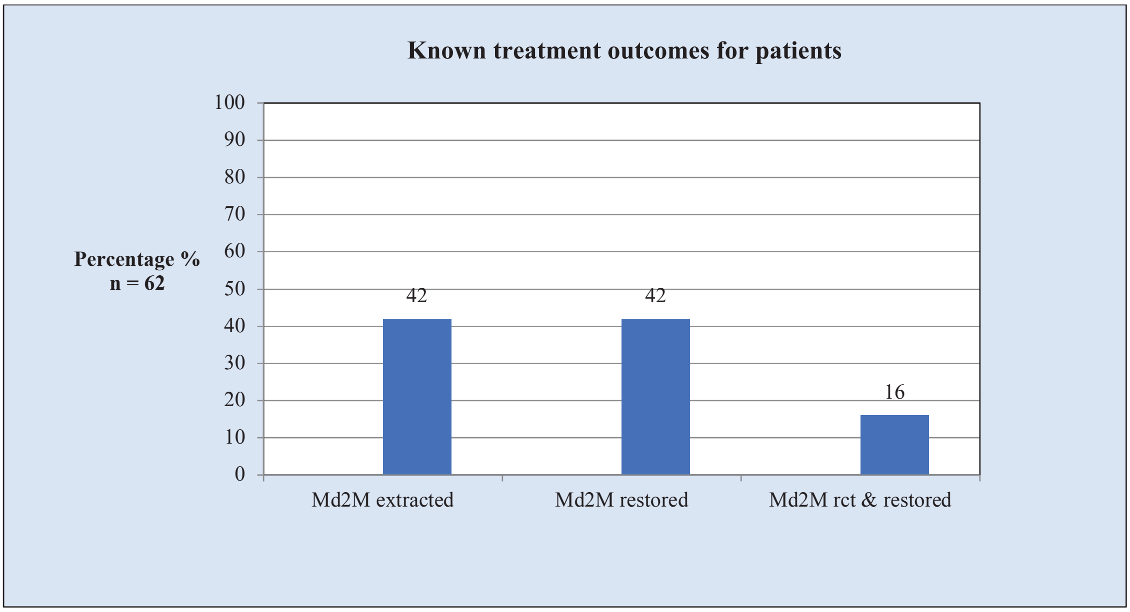
Figure 6.1 **Reported treatment outcomes for patients with DCC in Md2M.**



Legend: *This graph illustrates the percentage distribution of clinical outcomes for Md2M who had Md3M removed due to DCC on the Md2M. 30% of patients were aware that the Md2M had been removed; 30% restored; 12% restored including endodontics, with 27% of patients unsure of the treatment related to the Md2M (McArdle et al., 2016).*

Of the 62 patients who could recall the treatment outcomes for their second molar tooth, 26 patients (42%) had their second molar removed, 26 patients (42%) had their second molar restored and 10 patients (16%) had their second molar endodontically treated in addition to restoration (Figure. 6.2).

Figure 6.2 Known reported treatment outcomes for patients with Md2M DCC.



Legend: *This graph illustrates the percentage distribution of known clinical outcomes for Md2M who had Md3M removed due to DCC on the Md2M. 40% of Md2M were extracted; 40% restored, and 16% restored including endodontics (McArdle et al., 2016).*

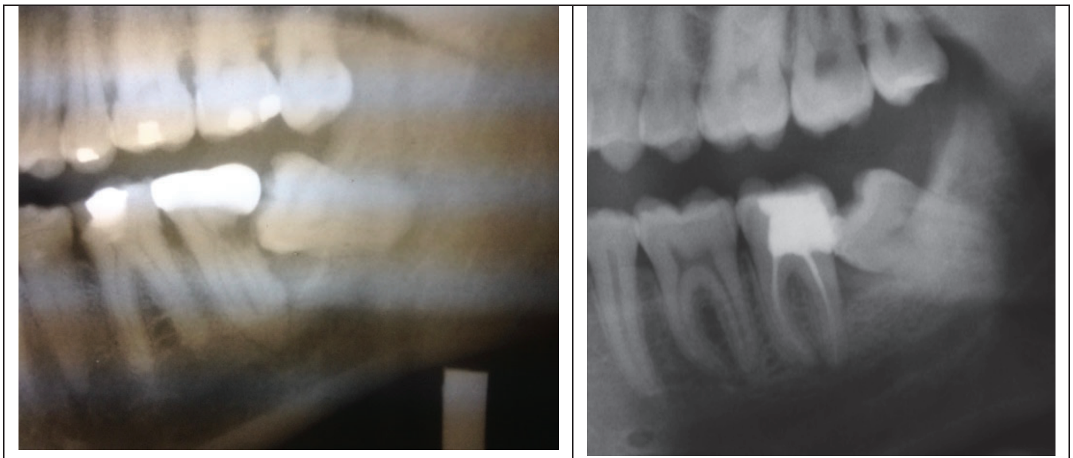
6.3 Discussion.

The majority of Md2M DCC is related to MAMd3M, which accounts for 90% of all cases, whereas a smaller incidence of Md2M DCC is observed with HORIZMd3M. Md2M DCC has not been observed in association with vertical, disto-angular, or ectopic Md3M impactions and has not been seen in the absence of an impacted Md3M (McArdle and Renton, 2006; McArdle et al., 2014).

Treatment outcomes for patients with Md2M DCC will generally include removal of the Md3M to facilitate restoration of the Md2M. Conservative treatment of the Md2M may involve uncomplicated restoration of the tooth but in some cases the tooth will also require endodontic treatment and more complex and expensive restoration. In other cases, it may not be possible to restore the Md2M and removal may be indicated either concurrent with the removal of the Md3M; later if restoration of the Md2M becomes unfeasible, or ultimately it may, in its own right, fail at a later stage once restoration has been undertaken and further disease ensues. In patients in which it is not feasible to restore the Md2M and this tooth is indicated for removal, the Md3M may, in some cases, be retained if it is disease free, as removal of the Md3M may be clinically meaningless. In the majority of cases of patients with Md2M DCC the immediate and long-term prognosis for this tooth is poor and the likelihood of the Md2M lasting indefinitely would be guarded.

Restoration of the Md2M whilst overlooking the need for removal of the Md3M is not clinically pragmatic. Retention of the Md3M will make restoration of the Md2M difficult and ultimately the Md3M will persist in compromising the Md2M either from the risk of secondary DCC or periodontal problems (Figures 6.3). In cases where potential Md3M removal will have a significant risk of IDN injury consideration may be given to undertaking a coronectomy procedure on the third molar to eliminate the casual influence and the potential effect of the third molar (McArdle et al., 2014). Retention of the Md3M will not eliminate the compromised anatomical relationship between the Md2M and the Md3M, and persistence of the Md3M will still restrict oral hygiene and result in subsequent secondary decay on the Md2M.

Figure 6.3 Images of further disease in compromised Md2M.



Legend: *These images illustrate further Md2M disease associated with MAMd3M. the left-side image demonstrates secondary Md2M DCC and periodontal disease as a result of retention of a MAMd3M. the right-side image demonstrates a restored Md2M that has been endodontically treated due to an impacted MAMd3M with secondary periodontal disease and a poor distal restoration on the Md2M.*

In estimating the cost of DCC, a number of factors need to be considered. The number of patients with DCC and the proportion of different treatment outcomes related to these patients have to be calculated. In addition, the direct monetary cost of each of treatment modality and the indirect costs of treatment need to be quantified. The cost of second molar DCC may be more difficult to calculate as, although the loss or restoration of a tooth has a financial cost, the ongoing long-term costs of maintenance and possible loss will change with individual circumstances. In addition, costs tend to be qualified, not only by these direct costs of the intervention, but also by the indirect costs for the patient such as loss of patients' earnings due to time off work, loss of productivity due to absence from work and intangible costs such as pain, incapacity and compromised occlusal function if the second molar is lost.

6.4 How many patients may be affected by DCC?

The incidence of caries as an indication for third molar removal has risen from less than 10% in 2000 to 30% in 2010 (McArdle, 2013; McArdle and Renton, 2012). This data was extracted from HES online datasets which doesn't allow caries to be categorised independently between caries affecting the Md3M and Md2M DCC as the primary indication for Md3M removal. It has been previously reported that Md2M DCC may contribute to between 5% - 40% of all Md3M removed (Allen et al., 2009; Bruce et al., 1980; McArdle and Renton, 2006). These figures, however, may be underestimated, and may be increasing as a consequence of the changing practice in the management of third molar teeth (McArdle, 2013; McArdle and Renton, 2012; Renton et al., 2012). The mean-age of patients having third molar removal has increased from 28 to 32 during this time period also which has been confirmed by the results of the study from chapter 2 (McArdle, 2013; McArdle and Renton, 2006; McArdle et al., 2014; McArdle and Renton, 2012). As the mean age of patients has increased and the incidence of caries has also increased, and it may be reasonable to presume that the rate and incidence of Md2M DCC will also have risen during this period. Data from chapter 3 highlights that the combined incidence of caries, C&RD and Md2M DCC, now accounts for 41% of all Md3M removed with Md2M DCC accounting for **14%** *of all Md3M removed* (McArdle et al., 2018). In terms of patients, as opposed to the number of Md3M removed, Md2M DCC accounts for **16%** *of all patients* from the dataset of 1011 patients having Md3M removed. Furthermore, DCC is seen predominately related to MAMd3M teeth and consequently the likely incidence of DCC solely related to mesio-angular third molar impactions will be substantially more (Allen et al., 2009; Chang et al., 2009; Falci et al., 2012; McArdle et al., 2014; McArdle and Renton, 2012; Oderinu et al., 2012; Ozeç et al., 2009). From this research, it has been demonstrated that Md2M DCC accounts for 44% of all MAMd3M removed and 9% of all HORIZMd3M removed (McArdle et al., 2018).

Data collection related to third molar removal is deficient in the UK as there is no accurate summative record of patients undergoing third molar removal on an annual basis (HES, 2018; McArdle, 2013; McArdle and Renton, 2012). In 2005, a new NHS General Dental Services contract was introduced and one of the consequences was that the NHSBSA no longer recorded any specific data for patients' treatment in primary dental care. Consequently, no data exists for third molar removal in primary care since 2004/5. In secondary care, in-patient and day-case activity is recorded and published through HES online and since 2004 HES has also published out-patient third molar removal as well but HES does not specify if the out-patient data relates to treatment undertaken solely under local anaesthesia or with dental chair conscious sedation *(sic)*. Historically, and contemporarily, most out-patient third molar removal has been recorded as a non-descript, 'out-patient episode' and tariffed accordingly (HES, 2018). Consequently, an out-patient appointment for third molar removal cannot be differentiated from an out-patient appointment for a review or any other out-patient treatment. Out-patient third molar removal under local anaesthesia is poorly recorded, underestimated and accounts for a significant proportion of secondary care third molar activity (HES, 2018). Nonetheless, using data from online Hospital Episodes Statistics (HES) and internal hospital dataset statistics we can estimate the volume of third molar removal undertaken on an annual basis. From HES online it was calculated that in 2013/14 there were approximately 67k patients requiring third molar removal as an in-patient or day-case hospital admission in England and 16k on an out-patient basis (HES, 2018). HES confirms that all out-patient treatment episodes only represent a proportion of all third molar activity as third molar removal under local anaesthesia within the hospital secondary care setting has generally not been recorded as an actual third molar treatment episode (HES, 2018).

Guys and St Thomas's NHS Foundation Trust (GSTT) is a large tertiary teaching hospital in central London. The Oral Surgery Department undertakes in excess of

2,300 patient treatment episodes for third molar removal on an annual basis. GSTT datasets, for 2014/15 were reviewed for procedure codes F0910 (surgical removal of impacted third molar) and F0930 (surgical removal of third molar). These determined that approximately 1500 patients were admitted for third molar removal under day-case general anaesthesia or sedation and 800 patients on an outpatient, local anaesthetic basis (GSTT, 2015).

If we consider the oral surgery department of GSTT NHS Foundation Trust to be representative of a typical secondary care oral surgery provider in England, and we extrapolate the GSTT ratio (15:8) of admitted third molar procedures to out-patient procedures and confer this ratio to national figures then based on the figure of 67k patients in England who had third molar removal on an admitted basis, then we can estimate the total combined volume number of patients in England having third molar removal in a secondary care setting. Based on this calculation we can estimate that nationally, in England, in the region of 38k patients have third molar removal on an out-patient local anaesthesia basis giving an estimated total of 105k patients for secondary care activity. These figures are conservative estimates of treatment volume and the expectation is that the numbers are more due to inefficient reporting of treatment within the NHS (Figure 6.4).

Figure 6.4 Calculation - estimated annual number of patients having third molar surgery 2013/14.

Calculated number of patients having third molars removed in secondary care to nearest 100	Ratio of patients in Secondary care having third molars removed admitted:out-patient From GSTT data 2014/15	Actual number of patients having secondary care admitted F0910/F0930 procedures 2013/14 HES figures	Estimated number of patients having secondary care outpatient F0910/F0930 procedures 2013/14	Estimated total number of patients having secondary care F0910/F0930 procedures 2013/14
	1500:800	67000	38000	105000 patients
Calculated number of patients having third molars removed in primary care to nearest 100	Actual number of patients having primary care Md3M 2204/2205 procedures. (2004/5 figures last published NHSBSA figures)	Estimated numbers of Md3M removed in primary care. calculated with reference to increase in secondary care activity of 72% between 2003-2014		Estimated total of patients for primary and secondary care
	28000	48000		153,000 patients

Legend: *This figure illustrates the calculation of notional patients having third molar surgery in England. Based on the actual figure of 67000 patients having third molar removal on an admitted/day-case basis and a ratio of 15:8, It is estimated that 38000 patients have third molar removal as an out-patient – total of 105000 patients/annum. In addition, it is estimate; based on a 72% increase in secondary care activity mirrored in primary, care that 48000 Md3M are removed on an annual basis. Combined total of 153,000 patients. These data trends suggest that these figures are fluid and that the numbers continue to rise on an annual basis.*

As stated, the NHS does not now record the number of patients having third molar removal undertaken in NHS primary care. The last year for which the NHS Business Services Authority (NHSBSA) recorded data was in 2004/5 and in this year, approximately 28k Md3M were removed in NHS primary care (NHSBSA, 2006). NHSBSA data recorded the actual *number* of third molar teeth removed as opposed to HES which records the number of *patients* having at least one third molar removed (McArdle and Renton, 2012; NHSBSA, 2006). It is not, therefore, possible to calculate the true volume of primary care third molar activity, as there are no contemporary datasets to make an accurate calculation. However, from 2002/3 to 2013/14 there had been increase in day-case hospital based activity of 72% (McArdle and Renton, 2012). For England, if the 72% increase in secondary care activity is mirrored in primary care treatment in England, then it can be estimated that 48k *Md3M* are being removed in primary care on an annual basis. This could relate to a minimum number of 24k *patients* having two Md3M removal in a single treatment episode or a maximum number of 48k *patients* who had a single Md3M removed in primary NHS care (Figure 6.4). The latter figure may be a more accurate estimation as NICE has encouraged the removal of only single asymptomatic third molars rather than combining with asymptomatic removal. Based on these actual and estimated numbers the minimum number of patients having third molar removal in England may, therefore, be in the region of 153k *patients*, however the actual number, in reality, may well be much higher (Figure 6.4).

For secondary care and based on 16% incidence of patients with Md2M DCC and the potential total of 105k patients per annum; and for primary care with an estimated number of 48,200 patients with 14% of 48,200 Md3M removed, it can be estimated that in England, potentially 23.5k patients per annum may now be being diagnosed with DCC in a Md2M tooth due to an impacted Md3M (Figure 6.5). In addition, it has been reported that approximately 20% of patients with Md2M DCC, as an indication for the removal of the third molar, have bilateral DCC (McArdle and Renton, 2006; McArdle et al., 2014). This results in a potential of approximately 27k Md2M teeth that may be affected by DCC as a result of an impacted Md3M tooth with 27k Md3M being removed as a consequence (Figure 6.5). Based on the outcome data of treatment of Md2M with DCC this may result in potentially 11.4k (42%) Md2M being extracted and requiring possible replacement; 11.4k (42%) that will require restoration, and 4.2k (16%) requiring root canal treatment and restoration (Figure 6.5). In addition, a proportion of patients may have complex restorative treatment undertaken then later lose the Md2M as well adding to the consequent cost. This proportion of patients is unknown from this data so is not calculated here.

Figure 6.5 Calculation - estimated annual number of patients with Md2M DCC having third molar surgery undertaken.

Estimation of Md2M DCC			Total
Day case/admissions	16% of 67k patient cases (2013/14)	10,720cases/annum (20% bilateral DCC)	12,864 Md3M/annum
Out-patient	16% of 38k patient cases (2013/14)	6,080 cases/annum (20% bilateral DCC)	7,296 Md3M/annum
Primary care specialist	14% of 48.2k Md3M	6,750 cases/annum	6,750 Md3M/annum
		23,550 cases/annum	26,910 Md3M/annum

Legend: *This figure illustrates the calculation of patients having third molar surgery due to Md2M DCC in England and the estimated number of Md3M removed due to Md2M DCC. 16% of patients attending for Md3M removal have Md2M DCC. 14% of all Md3M are removed due to Md2M DCC. This variation is due to the fact that 20% of patients have bilateral Md2M DCC when attending. 16% of 67,000 patients having third molar removal on an admitted/day-case basis and 16% of 38,000 patients have third molar removal on an out-patient – accounts for 10,720 patients and 6,080 patients/annum respectively (16,800). With 20% of these patients having bilateral disease this results in a total of 20,160 Md3M removed due to Md2M DCC. In addition, 14% of 48,200 Md3M removed in primary care, accounts for 6,750 patients/teeth on an annual basis. Total number of Md3M removed due to Md2M DCC approximately 27,000. Data trends suggest that these figures are fluid and that the numbers continue to rise on an annual basis.*

6.5 Direct financial costs.

Due to the idiosyncratic system of funding of NHS treatment in England, the true financial cost of treating this disease is difficult to quantify as primary care NHS treatment costs are based on courses of treatment rather than the actual service provision of a specific item of treatment. Courses of treatment are remunerated on units of dental activity (UDAs) which are remunerated at a variable financial rate dependent upon the individual dentist's contract. An UDA can attract a monetary value in the realms of £25 per UDA (NHSBSA, 2005). Courses of treatment are banded according to relative complexity with restorations and extractions identified as band 2 courses of treatment which attract 3 UDAs per course of treatment. More complex treatment requiring a prosthesis will be classed as a band 3 course of treatment and attract 12UDAs per course of treatment. Consequently, based on the funding provisions in England, the actual cost of either a simple restoration of the second molar or its removal in primary care may be in the range of £75 per case but for more complex treatment, including endodontics with a crown/inlay restoration, this may be in the region £300 per case (based on rate of £25/UDA) (Steele, 2009). For those patients with bilateral disease, treatment of both teeth during a single course of treatment will attract a *single* course of treatment fee so potentially the cost of remedial dental treatment for Md2M DCC will be isolated to 23.5k courses of treatment. The cost in terms of patients who choose private dental treatment and specialist NHS provision will be substantially more, however the calculations related to cost are based solely on NHS funding. The permutations of patients' treatment are many and complex. Some patients may have treatment done in a single course of treatment and others two courses of treatment. In addition, some patients will have more complex and expensive treatment undertaken which will reflect in the overall cost. At the one end of the spectrum 23.5k patients affected by Md2M DCC may require a single band 2 course of treatment which would cost in the region of £1.7m for remedial treatment. At the other end, the cost may be in the region of £3m if those requiring endodontic treatment also require a crown to restore the tooth. This type of treatment would be in band 3 and attract a larger fee for 12UDAs of remedial treatment. Figure 6.6 demonstrates some of the permutations of treatment. Accordingly, based on NHS primary service funding, the primary care cost of treating Md2M DCC conservatively may be between **£1.7m - £3m** per annum in England. calculation based on lower and upper estimations of Md2M DCC teeth in patients (Figure 6.6).

Figure 6.6 Estimated costs of treating Md2M DCC in NHS primary care based on 2013/14 estimated figures.

Treatment outcomes for patients with Md2M DCT (% proportion)		Md2M Extraction (early and late)	Md2M Restoration	Md2M endodontics and restoration (cost if Rx includes crown)
		42%	42%	16%
Estimated number of Md2M (27,000) in 23.5k patients		11400	11400	4200
Unit cost for treatment. Primary care £25/UDA Band2 = 3UDAs (Band3 = 12UDAs)		£75	£75	£75 (£300)
Cost for 23.5k band2 courses of treatment - if all patients with bilateral disease (20%) are treated as a single course of Rx.	23.5k x £75 = £1.7m			
Cost for 23.5k courses of treatment – with 84% band2 and 16% band3 course.	£2.6m	£0.75m	£0.75m	£1.1m
Cost for 27k band2 courses of treatment - if patients with bilateral disease (20%) are treated as two courses of Rx.	27k x £75 = £2m			
Cost for 22.8k band2 courses of treatment – and 4.2k band3 course of treatment	22.8k x £75 + 4.2k x £300 = £3m			
Total cost for Rx **(£1.7m - £3m)** (£3m if all endodontically treated and crowned)		£0.85m	£0.85m	£0.3m (£1.3m)

Legend: *This figure illustrates the estimated cost of remedial dental treatment of Md2M for patients with Md2M DCC. Based on band 2 course of treatment (£75) and band 3 course of treatment (£300). Sample permutations of 23.5k courses of band 2 treatment costing £1.7m. If those patients requiring endodontic treatment also have Md2M crown placed (4.2k) then cost at upper limit would be £3m. Total cost of remedial treatment £1.7m-£3M*

In hospital based secondary care the total cost of third molar removal will be in the range of £1000 per case for day-case procedures and £400 per out-patient procedure as based on the 2014 NHS treatment tariffs (NHS, 2014). These costs are inclusive of initial outpatient consultations, radiographs, etc. For patients with Md2M DCC, the cost amounts to approximately **£10.7m** for third molar management under day-case [(67k patients x 16% proportion with Md2M DCC – 10,720 cases) x £1000/case = £10.7m] and **£2.4m** for third molar management on an out-patient basis [(38k patients x 16% proportion with Md2M DCC – 6,080 cases) x £400 = £2.4m]: A total of **£13.1m** per annum (Figure 6.7).

Management of impacted third molars in primary care is now being regularly provided by primary care based oral surgery specialist services. In NHS primary care, oral surgery specialist care costs are in the region of £150-£250 per case (NHS England, 2014). Unfortunately, the NHS does not calculate the amount or proportion of work provided by this group, however if the primary care estimate of 48k Md3M is accurate then the volume of primary care Md3M removals due to DCC, may be of the order of 6,580 cases (14%). This would result in an estimated cost of primary care Md3M removal between **£1-£1.7m** per annum (Figure 6.7).

Figure 6.7 Cost of third molar removal in the NHS based on 2013/14 estimated figures.

Costs for third molar removal of Md2M DCC patients				
Day case/admissions	16% of 67k cases	£1,000/case	10,720cases/annum	£10.7m
Out-patient	16% of 38k cases	£400/case	6,080 cases/annum	£2.4m
Primary care specialist	14% of 48.2k Md3M	£150-£250/case	6,750 cases/annum	£1m-£1.7m

Legend: *This figure illustrates the calculation of costs for patients having third molar surgery due to Md2M DCC in England. The estimated cost of Md3M removal in secondary care is £13.1m per annum and for primary specialist care, £1m-£1.7m. A total of £14.1m -£14.8m per annum (2013/14)*

The loss of the Md2M tooth may not significantly influence masticatory function or aesthetics so, consequently, clinical indications to replace this tooth will be limited. However, potential over-eruption of the opposing maxillary second molars and patient choice to maintain an optimal functional dentition may otherwise indicate replacement of the Md2M tooth. Treatment options would exclude conventional bridge-work due to the lack of a distal abutment and patients would generally respond poorly to replacement with a conventional denture. Consequently, the optimal treatment choice for the replacement of the Md2M would be with an implant retained crown. Not all patients may be suitable for dental implant treatment but patients with Md2M DCC do tend to have better dental health than average and would probably be suitable for implant treatment (McArdle and Renton, 2006; McArdle et al., 2014). Patients, however, may also be less inclined to undergo implant treatment due to the requirement of further surgery; of potential inferior dental nerve morbidity and the time commitment of such a treatment option. It is difficult, therefore, to speculate how many patients would wish to replace a Md2M tooth, but with the cost of this treatment being, on average approximately £2.5k per implant-retained crown, this treatment option could total **£28m** per annum if all patients (11.4k/annum) who are estimated to have lost their Md2M elect to have this treatment. Implant treatment on the NHS is generally limited to patients who have lost teeth due to trauma or malignancy, or who have missing teeth due to hypodontia or failed orthodontic alignment of impacted canines.

It is unlikely that NHS commissioners would fund the replacement of the Md2M with an implant retained crown as the clinical indications for replacement would not fulfill NHS implant treatment guidelines. However, patients may become sensitive to the fact that the retention of the impacted Md3M has resulted in DCC of the Md2M and that early removal could have prevented this from arising. As awareness of this condition and its causes becomes more widespread claims for repair and replacement of the Md2M may become commonplace. Patients and medico-legal lawyers may perceive a failure to intervene early with the at risk Md2M as supervised clinical neglect and argue that loss of the Md2M and consequent function was avoidable had the dentist addressed the potential for DCC in the Md2M. As the increase in frequency of Md2M DCC has been brought about by the indirect consequences of NICE guidance it may be that the NHS will be indirectly liable for these costs.

6.6 Indirect financial costs.

Indirect costs are made up of loss of patient's earnings and loss of access for other patients, however these indirect costs of third molar removal can be more difficult to quantify.

Costs such as loss of patient's employment productivity and potential loss of earnings for patients having to attending for both third molar removal and for remedial dental treatment may add another notional **£7.4m/annum** loss of earnings for time of work for third molar surgery and recovery plus **£1.5m/annum** loss of earnings for the time spent on remedial treatment of the second molar (Figure 6.8). The former is calculated from the number of patients requiring third molar removal due to DCC (23.5k patients/annum), the average recovery period for patients having third molars removed (3 days) and the resultant loss of earnings based on the UK average earnings value (£27.2k/annum) ref. The latter is similarly calculated from the potential number of patients experiencing DCC (23.5k patients/annum with 27k second molars/annum); an estimated average of 3 hours/Md2M tooth of a patient's time to attend the dentist for remedial treatment (including traveling time); and the loss of earnings based on UK average earnings value (£27.2k/annum) (Mitchell, 2011; ONS, 2014a; Phillips et al., 2010). The financial cost to the economy is more difficult to quantify, however as these patients will generally be adults in their 30's the cost to the economy will be sizeable.

Figure 6.8 **Indirect patients cost for treatment of Md2M DCC.**

Indirect costs, national average salary 2014 £27.2K/annum £523/week £105/day £14.14/hour (37hrs/week)		Notional 23.5k patients having Md3M removal /annum	Notional 27k Md2M to be treated for remedial work
Time off work for Md3M surgery	Average 3 days £315/patient	£7.4m	
Time off work for remedial dental treatment	3hours per Md2M tooth £56		£1.2m

Legend: *This figure illustrates the calculation of indirect costs for patients having third molar surgery due to Md2M DCC in England. The estimated indirect costs of Md3M removal are £7.4m for loss of 3 days earnings after Md3M removal and £1.2m for 3 hours loss of earnings of attending the dentist for remedial treatment of the Md2M: total of £8.6M (2013/14)*

For the dentist, themselves, remedial treatment may require an additional 27k work-hours/annum. Treatment for 27k Md2M in 23.5k DCC patients is treatment that is potentially avoidable and this treatment time and money should be spent on treating other patients. Remedial treatment for Md2M DCC, in effect, diverts resources and reduces access for other patients that will still have to be treated. This could be another 27k courses of band 2 treatment to the work load of the dentist and calculated at £75 per band 2 course of treatment (calculation based on a notional 30 min clinical time for simple band 2 course of treatment at £75 and 27k courses of treatment). This may add a further notional £2m/annum in indirect costs. This should not be considered as double accounting, as dentists undertaking treatment for potentially avoidable Md2M DCC will still be have to provide access and treatment for other patients' treatment.

Overall the potential costs of treating second molar DCC are substantial and could potentially eclipse £55m per annum (Figure 6.9).

Figure 6.9 Total costs of treating patients with Md2M DCC.

	Total costings of treating patients with Md2M DCC	Actual additional costs of managing Md2M DCC excluding Md3M management
Md3M removal	£14.1m - £14.8m	
Md2M DCC management	£1.3m – £3.1m	£1.3m – £3.1m
Patients' costs, loss of earnings, etc.	£8.6m	£1.2m
Dentist costs, additional work.	£2m	
Potential cost of replacing Md2M with implant retained crown	£28m	£28m
Total	**£54m-£56.5m**	**£2.5m – £32.3m**

Legend: *This figure illustrates the summary calculation of all costs for patients having third molar surgery due to Md2M DCC in England. The estimated total costs inclusive of Md3M removal are £26m -£28.5m if implant treatment excluded and £54-56.5m if implant treatment included. The true additional costs are £2.5m to £32.3m. (2013/14)*

6.7 Supplementary considerations

NICE guidance has resulted in a change of practice towards managing *teeth* rather than managing *patients* (McArdle, 2013; NICE, 2000). NICE proscribes the removal of an asymptomatic impacted third molar tooth even when a separate symptomatic third molar is being removed. Patients often have only a single problematic third molar removed in isolation whilst other impacted, but as yet asymptomatic, third molars are disregarded. It would seem prudent; therefore, to consider the long-term potential of disease from leaving these asymptomatic impacted third molars rather than ignoring it to deal with disease in the future. As Md2M DCC is a late presenting disease many patients with it may be subjected to multiple treatment episodes for individual third molar management over a long-term period rather than a single treatment episode for all third molars (McArdle, 2013; McArdle and Renton, 2006; McArdle, et al., 2014). This in itself increases potential costs, as tariffs for third molar removal will be based on treatment episodes, irrespective of how many third molars are removed. With patients having a potential four third molars this could theoretically translate into four treatment episodes rather than a single, collective treatment episode for patients with third molars. Patients who have multiple treatment episodes will invariably cost the NHS and other funders more to treat over a lifetime than a single treatment episode. An holistic approach, whilst considering the potential for further problems of third molars may, in fact, be less detrimental to the patient and save money in the long-term (McArdle, 2013). In terms of the diseased Md2M the restoration of the Md2M DCC may only be the start of further restoration, future endodontic treatment and eventual removal of the tooth with each and subsequent intervention adding to the overall financial burden and pushing up consequential costs further.

All mesio-angularly impacted Md3M teeth pose a risk of DCC to the second molar tooth (McArdle, 2019; Toedtling, 2015, Falci et al., 2012). The risk and consequence of Md2M DCC is not always realised as a significant proportion of third molars are removed prior to the formation of DCC. As has been shown pericoronitis accounts for the majority of Md3M removal in patients who are generally younger than those with Md2M DCC. It is those susceptible teeth that are retained later into life that result in Md2M DCC formation, hence the apparent small proportion of patients who experience the disease. With more patients retaining third molar teeth into the fourth decade of life and the incidence of third molar related caries rising then this is a situation that will only deteriorate further with more additional costs. By considering prophylactic third molar removal in this situation, we are not providing unnecessary treatment with an unnecessary financial cost to the NHS or independent funder. We are investing in an intervention that will reduce the global cost for treatment in an individual as well as the overall cost for the NHS. If left these patients will cost more to treat with mounting ongoing costs. If the risk of Md2M DCC is high, then removal of these retained Md3M has a definitive cost-benefit for the patient, the NHS and society as a whole.

6.8 Conclusion

In this chapter, the outcomes of treatment for patients with Md3M related DCC of the Md2M and the potential costs for its management have been highlighted. Md2M DCC is an avoidable and preventable disease of the Md2M tooth. The risk of DCC forming on the Md2M can be eliminated by the removal of the Md3M tooth before DCC occurs but this would involve the prophylactic removal of those third molars that pose this risk. The cost of preventing DCC on the Md2M tooth would still involve the direct and indirect costs of Md3M removal so the actual savings to be made in a management model that advocates prevention may be limited to the direct costs of managing the Md2M and the indirect costs to the patient in terms of loss of earnings: this would still be in the range of £2.5m-£32.3m per annum. Intangible costs such as pain and occlusal compromise are more difficult to quantify from a financial perspective. These costs are wholly avoidable if the potential for Md2M DCC is identified early and the appropriate intervention of Md3M removal is advocated. However, if we continue to treat third molar teeth in isolation and only when symptomatic, patients' long term dental health will be compromised rather than consider patients as a whole, then these potential multiple treatment episodes will incur further unnecessary costs of multiple third molar removal. Potentially, this may, at the worst, double the cost of third molar removal for each of these patients by another £20m per annum

Accepting all the assorted costs, both financial and subjective, of managing Md2M DCC as consequence of avoiding early prophylactic removal is inappropriate as this underlines a degree in apparent corporate institutional obstinacy. If groups of patients are at risk of Md2M DCC then both dentist and patient need to be educated to the risks and the relevant treatment options rather than be constrained by NICE guidance. The 2013 Supreme Court determination on the Montgomery v Lanarkshire Health Board determination regarding patients right to being informed of '…any material risks', related to an intervention hold as equally as to being informed of the material risks of non-intervention (Montgomery, 2015). Patients have the right to know what the potential outcomes of third molar retention are. Patients at risk of Md2M DCC should be informed of this potential and allowed to decide if their impacted third molar teeth should be removed.

Chapter 7

Conclusions, management and summation

7.1 Conclusions

The mean age of patients requiring third molar removal has risen steadily from 26 years in the early 90s through to 28 years by the turn of the century and for the last 10 years has been 32 years.

As the mean age of patients has increased, the frequency of ‘caries & related disease’ has also increased. Pericoronitis is still the most common disease indicating the removal of impacted mandibular third molars in 49% of cases. Based on HES figures, ‘caries & related disease’ has increased in frequency as an indication by over 300%; from approximately 7% of patients prior to the introduction of NICE guidance to 30% of patients in 2010. In this data set 41% of mandibular third molars are removed due to caries and related disease.

Over the last 20 years distal cervical caries of the mandibular second molar has become a more frequent diagnosis and accounts for 14% of all mandibular third molars requiring removal. Distal cervical caries is only seen in association with mesio-angular and horizontal mandibular impacted third molars; accounting for 9% of horizontal impacted mandibular third molars and 44% of all mesio-angular impacted mandibular third molars. It is not seen in the absence of an impacted mandibular third molar.

Distal cervical caries is more commonly seen in patients over the age of 30 years with the incidence of distal cervical caries associated with mesio-angular mandibular third molars increasing with age whilst pericoronitis decreases. For patients between the age of 20-29 years of age, 30% of mandibular third molars are removed due to distal cervical caries. For patients 30-39 years, the incidence is 62% and for patients 40-49 years, 70%. Pericoronitis in contrast accounts for 46% in the 20-29 year range, 13% in the 30-39 year range and 0% in the 40-49 year range.

In relation to patients requiring removal of mesio-angular impacted mandibular third molars, the mean age of patients with a diagnosis of pericoronitis is 25 years; 31 years for caries & related disease and 33 years for distal cervical caries of the second molar. Pericoronitis is generally a disease observed in younger third molar patients with caries & related disease, and distal cervical caries observed in older patients. Not all patients at risk of distal cervical caries do develop it; as a significant cohort of potential patients with impacted third molars succumb to other diseases, notably pericoronitis, before distal cervical caries can occur on the second molar. Predicting who will get distal cervical caries has a clinical paradox as all patients with a mesio-angular mandibular third molar are theoretically at risk of getting it but most patients will lose their third before the age of 30 years due to other diseases and therefore for a significant proportion of patients distal cervical caries of the second molar will not be realised. The increasing frequency of patients having third molars removed due to distal cervical caries as they age suggests that the majority of partially erupted mesio-angular mandibular third molars would eventually result in distal cervical caries of the second molar.

The potential population pool for distal cervical caries becomes smaller as patients age because patients will steadily lose their impacted third molar teeth due to disease but those that retain them are more likely to have them removed due to distal cervical caries.

Pericoronitis and distal cervical caries of the mandibular second molar do not have distinct ICD10 codes and consequently NHS datasets do not record data appropriately to measure disease rates on a national level. Ideally these diseases should be given appropriate codes to address this.

The common features of patients with distal cervical caries of the mandibular second molar include; an impacted partially erupted mesio-angular or horizontal mandibular third molar tooth; better dental health than average with a DMFT score approximately 50% less than the average, from comparable age groups in the ADHS 2009 patients; and they tend to be, on average, 5-8 years older than patients requiring mandibular third molar removal due to pericoronitis.

Diagnosis of mandibular second molar distal cervical caries will require the removal of the impacted third molar to facilitate treatment of the second molar. Approximately 40% of mandibular second molar teeth associated with distal cervical caries will eventually require removal; 15% will require root canal treatment and restoration and 40% will be conservatively restored. The long term prognosis of all restored mandibular second molar teeth will remain uncertain.

Bacteriological studies of distal cervical caries lesions demonstrate that these lesions are typical of other deep dentine penetrating lesions on teeth. Dilaster, Prevotella and

Lactobacillus genus are the predominant bacteria found with these lesions and that inter patient bacteriological profile of distal cervical caries lesions are comparable with one another.

The cost of treating Md2M DCC, exclusive of the cost of removing the mandibular third molar, will be in the estimated range of £1.7m-£3.0m per annum for clinical treatment and £1.5m per annum for patients' loss of earnings and productivity: up to £4.5m per annum. If remedial implant replacement treatment for the second molar is factored into this then a further £28m could be added. Total additional cost in the range of £3.2m - £32.6m per annum.

The partially erupted mesio-angular impacted mandibular third molar is significantly linked to the development of distal cervical caries on the second molar and becomes increasingly more frequent in patients who retain their impacted third molars into later life. The early removal of mesio-angular impacted third molars will prevent formation of this disease. Appreciation of the progression and the disease outcomes of retained impacted third molars should be acknowledged and consideration should, therefore, be given to early intervention.

In this series of studies, we had identified the null hypothesis to be that the introduction of NICE guidance has not affected the profile of disease or treatment of third molars.

In relation to the null hypothesis, the evidence demonstrates that the introduction of NICE guidance has resulted in a change in the profile of third molar disease with patients demonstrating a higher frequency of caries related disease as the primary indication for third molar removal. Patients were found to be older and the data demonstrated that more patients were having impacted third molars removed than prior to the introduction of NICE guidance. The rate of increase in patient numbers was greater than the rate of population change.

The null hypothesis has therefore been rejected.

7.2 Management of Md2M DCC.

Not every Md2M associated with a partially erupted MAMd3M or HORZMd3M will result in DCC, however it is not the case that only some Md2M will be at risk; hypothetically all MAMd3M and HORZMd3M will have the potential to cause DCC. The reason we do not see DCC in all cases is that DCC is a late consequence of Md3M retention and in most cases the partially erupted Md3M will be removed before DCC will occur. Approximately 60% of all impacted Md3M are removed before the age of 30 years with pericoronitis accounting for 65% of all Md3M removed in patients below this age (McArdle, 2018). Consequently, a large number of patients who could otherwise succumb to DCC become eliminated from the 'at-risk group' before DCC can result because their Md3M is removed before it can form. Conversely, those patients who retain a partially erupted MAMd3M demonstrate an increasing frequency of DCC as they become older, suggesting that the longer the third molar remains retained, the likelier it will be to result in Md2M DCC (McArdle et al., 2018). As patients age, the total number of patients retaining an impacted Md3M will continually diminish as third molar disease will eventually occur resulting in removal. It is estimated that 80% of all patients with impacted third molars will require removal by the time they are middle aged (McArdle et al., 2018; Brickley et al., 1996: Hugoson, 1988)

7.2.1 Prevention and treatment of Md2M DCC.

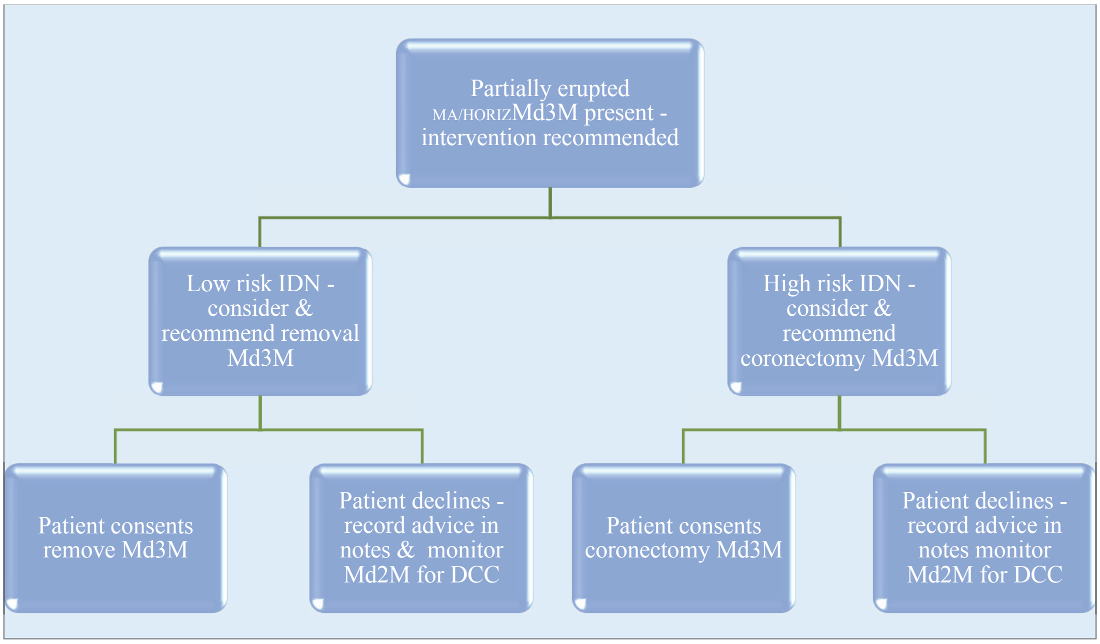
The asymptomatic partially erupted MAMd3M or HORZMd3M should not be overlooked as a source of disease potential. Md2M DCC lesion can be difficult to detect clinically and although it has been suggested that regular review and radiographic assessment of patients at risk of DCC should be undertaken to aid in diagnosis of those at risk, this approach is counter-productive (Toedtling et al., 2016). The location of DCC can be deep on the root surface of the Md2M and consequently routine bitewing radiographs may not localize the lesion. Radiographic monitoring has one significant limitation, as once the caries has established itself then the removal of the third molar is indicated to permit restoration and to prevent re-occurrence of the DCC. In effect, an opportunity has been missed to prevent the formation of DCC.

As stated, the majority of patients who succumb to DCC have better than average dental health as measured by DMFT (McArdle et al., 2014). NICE's guidance on dental recalls would notionally afford patients with low DMFT scores the longest recall period of 24 months between dental examinations due to their relatively good dental health (NICE, 2004). This may again be counter-productive in that if DCC becomes established in a Md2M then its progression may go unchecked for some time resulting in a more extensive lesion that may require root canal treatment or even extraction.

In terms of overall patient management, this poses a problem in that the potential development of DCC would suggest that consideration should be given, contrary to NICE guidance, that the MAMd3M or HORZMd3M should be removed before DCC can occur. In managing patients with an asymptomatic partially erupted MAMd3M or HORZMd3M, both the dentist and the patient need to appreciate that there is material risk of DCC forming due to the long-term retention of these types of Md3M. A discussion, therefore, should be had with patients who are at risk of DCC occurring about their individual long term risk, the potential complexity of restoring DCC on the Md2M or the possible need for its removal, and the added necessity for third molar removal as well. In the opinion of the author all partially erupted MAMd3M or HORZMd3M pose this risk and all should be considered and recommend for prophylactic removal. It is always a patient's right to decline advice or treatment, however the dentist has a duty to the patient to put their interests first and advise them accordingly. Retaining an impacted MAMd3M or HORZMd3M that has the risk of contributing to disease on adjacent teeth with the potential long-term loss of the Md2M cannot be overlooked even if NICE's guidance proscribes us from recommending removal of such an otherwise asymptomatic tooth.

Where indicated, patients should be advised of the relative risk of DCC and consideration be given to early intervention – in most cases this would indicate the removal of the Md3M, however the nature of the intervention and the material risks of removal must also be considered. Post-operative surgical morbidity, in terms of pain and recovery, are generally self-limiting; surgical complications such as alveolar osteitis and infection can be relatively common post-extraction, though treatment is relatively simple. More significantly the relative risk of inferior dental nerve (IDN) and lingual nerve (LN) injury needs to be considered and correctly assessed – there is no advantage in securing the long-term health and retention of the Md2M but causing permanent IDN or LN injury as a consequence. In confirmed high risk cases for IDN injury coronectomy may be an appropriate intervention to ensure longevity of the Md2M whilst minimising the risk to the IDN. Indeed, no intervention may be decided upon if IDN injury risk is high and acceptance that the loss of the Md2M may be an ultimate but acceptable consequence – the possible long-term loss of the Md2M will be, by far, a better outcome than third molar removal and permanent nerve injury (Figure 7.1).

Figure 7.1 Management algorithm of patients at risk of Md2M DCC.



Legend: *This figure demonstrates the clinical algorithm for managing patients who are at risk of Md2M DCC. Consideration should be given for the removal of the Md3M unless the risk of inferior dental nerve injury is high as a consequence of Md3M removal.*

Consent can be a complex process and it is important that patients understand the nature and outcomes for any treatment intervention, however they also need to understand the outcomes of no treatment as well. Where no treatment may result in consequent disease and more complex treatment at a later stage then patients should be informed of this risk and the potential outcomes. The Montgomery v Lanarkshire Health Board case emphasised the notion of material risk and the value that a patient may place on the relative risks of an intervention, however this principle is also true in terms of the material risk of non-intervention and consequently it is the dentist's duty-of-care to inform a patient of the relative material risks of non-intervention too (Montgomery, 2015). In this way, patients can make informed choice related to risk and possible treatments. It is equally important that when identifying risk that any discussion with the patient, related to risk is recorded in the clinical notes. In the face of the evidence, failure to appreciate risk and to document decisions related to it could be misinterpreted as clinical ignorance or at worst as supervised neglect. Relevant documentation will support the clinician if patients question the reasons for not intervening early with a third molar when posing a risk to a now carious and unrestorable second molar.

For those patients who become diagnosed with DCC, restoration or extraction of the Md2M is indicated. Where restoration is planned the third molar will have to be removed to facilitate restoration. Attempting to restore the Md2M with the Md3M still present can result in a compromised restoration and leave the Md2M at risk of further DCC. If the Md2M is unrestorable, or if the patient chooses removal then consideration may be given to retaining the Md3M, especially if the risk of IDN injury is high. Often the Md2M can be restored, however access can be difficult due to the relative depth of the DCC on the root, restricting positioning of a matrix band distally to a good margin for a restoration. Endodontic treatment of the second molar is often indicated as caries can rapidly penetrate into the pulp resulting in more extensive and expensive treatment.

NICE presents us with a paradox when faced with DCC of the Md2M. The early, prophylactic loss of the Md3M will prevent DCC from forming but this is contrary to NICE's guidance were removal is indicated only in the presence of disease. NICE guidance does need to be reviewed and improved but NICE's guidance is not solely a list of clinical indications for third molar removal. NICE supports any decision related to third molar management as the guidance clearly states that it is just that – guidance; it is neither a guideline nor a treatment algorithm. Unfortunately, non-clinical stakeholders, such as the NHS and private commissioners of care, have been misinterpreting the guidance in a monochrome manner to justify fiscal policies of saving money and not focusing on the needs and benefits of the individual patient. With finite amounts of resources, the general objective is to optimise resources and minimise cost where possible and third molar management is easy prey to such a policy.

7.3 Summation

It is practically impossible to ascertain whether all partially erupted MAMd3M or HORZMd3M would result in Md2M DCC given appropriate time. A confirmative answer to this would indicate the need to consider early prophylactic removal before DCC ensues and this would have significant repercussions for NICE, the dental profession, and for patients. However, the data presented in this thesis and published papers does suggest that prophylactic Md3M removal should have a role to play in the prevention of DCC in the Md2M tooth.

The data presented in this thesis provides only part of the evidence towards understanding the features and the comparative risk of DCC occurring. However, the data and knowledge accumulated go in part to understanding the nature of DCC, the patients who succumb to it and the need to consider prophylactic Md3M removal as a legitimate treatment for the prevention of Md2M DCC. Further research is required on a national scale which can further the understanding of the requirements for selective prophylactic Md3M removal.

The nuances of DCC, combined with ideal research strategies and the complexities of statistical data evaluation do not necessarily compute with one another in easily determining if prophylactic removal of MAMd3M or HORZMd3M should be undertaken to prevent DCC from forming.

Proving that all MAMd3M or HORZMd3M will eventually give rise to Md2M could be undertaken with a longitudinal cohort study observing a group of patients with partially erupted MAMd3M or HORZMd3M to see how many succumb to the disease. However, the length of time required to observe the required outcome would be far too proscriptive to adequately acquire the necessary information. With the mean age of patients being 32.7 years and the SD of 7.3 years would suggest that patients would have to be followed up until they are at least 40 years of age to adequately observe the occurrence of DCC. Patients within one standard deviation of the mean age would capture approximately 80% of patients. Patients would have to be recruited as soon as their Md3M teeth showed signs of partial and failed eruption in a MAMd3M or HORZMd3M position and would be expected to remain part of the study for a significant proportion of their formative life through to early middle age. Failed eruption of the Md3M could be anytime between 18 and 24 years thus making the time frame of observation in the region of 20 years. These individuals constitute a relatively mobile population group and following them up over such a time period would be extremely impractical. In addition a significant proportion of patients will readily succumb to pericoronitis early on (mean age 25 years), resulting in the observational cohort shrinking in size as patients become older as a consequence of early disease processes indicating the removal of the Md3M. Eventually this would highlight that only a certain proportion of all patients developed DCC. Patients would be lost to follow up and other disease and mobility. The numbers to recruit would be in the 10s of thousands to allow for a final cohort of 500-1000 patients – hugely impractical and almost a career for any willing investigator.

Alternatively, a randomised control trial comparing treatment (early prophylactic removal) with no treatment (prescribed retention of the third molar). A cohort of patients would have their Md3M removed early – as soon as eruption has failed and then observed for a period of time to see how many developed DCC and how many did not. Obviously, none would develop DCC, however outcomes in terms of morbidity, complications and costs would have to be determined and compared eventually with the second cohort. The second cohort recruited would ideally have their Md3M intentionally retained until they were 40 years of age to see how many developed DCC – recurring episodes of pericoronitis would be treated palliatively with antibiotics and local measures, with no surgical intervention permitted. Only once DCC formed would the patient be allowed removal of the Md3M and therefore leave the study. At the end of the study this group could be assessed to see how many episodes of pericoronitis that patients may have suffered, how many succumbed to Md3M caries and how many succumbed to Md2M DCC. In addition how many impacted Md3M remained asymptomatic with no disease could also be ascertained. This would, however, involve another 20 year study with a large number to recruit and probable high fall out rate. However, ethics would never be granted for a such study that requires patients to suffer one disease to see if they eventually succumb to another.

Measuring the relative risk of DCC forming will be difficult to truly calculate as although the group exposed to the risk of DCC may only demonstrate a limited number of cases over a defined period of time. The fact that DCC is seen in mainly in older patients and in a contracting population of potential patients masks the paradoxical bias that earlier removal due to pericoronitis will have on the relative risk and the eventual outcome for the patient. It could be wrongly concluded that not all patients get DCC so those that did not were never at risk. However, the converse is true in that all are at risk but early disease and disorders have contrived against the formation of DCC by creating an indication for the earlier removal of the Md3M before Md2M DCC can occur.

Proving that every patient with a partially erupted MAMd3M or HORZMd3M tooth is at risk of Md2M DCC, is therefore difficult to substantiate. Standard research protocols do not often sit comfortably with clinical research due to the ethical issues and time frames that they require. Acquiring high level research to determine best practice is therefore problematic and lower levels of research and consensus opinion may become the only source of research from which to determine best practice. These lower levels of research are often seen as poor or bad research as they do not eliminate research or personal bias from the equation however they may be the only source of research data available to us. This lack of research evidence of the required level does not indicate evidence of absence of any beneficial or detrimental effect of what is being proposed. However, the lack of high level evidence continues to obstruct meaningful debate between stakeholders such as NICE and the dental profession. RCTs appear to be the only language that stakeholders will countenance whilst lower levels of evidence are rejected and deemed inadmissible. If high level evidence does not exist and cannot be acquired, then other levels of evidence become the pinnacle of evidence base and should not be ignored nor discarded. NICE needs to move its mind set into the reality of what research is achievable and available rather than what is ideally best. We live in the real world and the concept of real-world evidence is becoming an important tool to compliment RCTs or where RCTs are impractical to give a certain degree of authority to other forms of clinical research that reflect the true reality (Survana, 2018).

Although NICE appears to have rigid clinical indications for third molar removal, the guidance does attest that, '*...**the guidance does not override the individual responsibility of health professionals to make the appropriate decisions in the circumstances of the individual patient and in consultation with the patient.***'. This fact is often ignored by non-clinical stakeholders who merely see the guidance as an instrument of compliance, ignoring the fact that the health and well-being of the individual patient should always be at the foremost of the clinical decision process.

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Appendices

Appendix I

Third molar proforma.

Third molar study

Complete for all third molars requiring surgical intervention (either extraction or coronectomy)

patient label

Age at presentation:

Gender:

DMFT score:

Third molar	Present-Absent	Primary indication for removal	Eruption state	Angulation
18	☐ - ☐	________ ☐ removal not indicated	Erupted ☐ P/Erupted ☐ Unerupted ☐	M/A ☐ D/A ☐ Vertical ☐ Horizontal ☐ Ectopic ☐
28	☐ - ☐	________ ☐ removal not indicated	Erupted ☐ P/Erupted ☐ Unerupted ☐	M/A ☐ D/A ☐ Vertical ☐ Horizontal ☐ Ectopic ☐
38	☐ - ☐	________ ☐ coronectomy ☐ removal not indicated	Erupted ☐ P/Erupted ☐ Unerupted ☐	M/A ☐ D/A ☐ Vertical ☐ Horizontal ☐ Ectopic ☐
48	☐ - ☐	________ ☐ coronectomy ☐ removal not indicated	Erupted ☐ P/Erupted ☐ Unerupted ☐	M/A ☐ D/A ☐ Vertical ☐ Horizontal ☐ Ectopic ☐

Notes:
Examples for mandibular third molar removal – pericoronitis; caries in third molar; DCC in 2nd molar; periodontal disease, abscess 2^{0} to caries?/perio?; early/established cyst formation; orthodontic/gnathic; resorption of adjacent tooth; etc, etc.

Examples for maxillary third molar removal – as above but may also include, cheek biting; food packing; overeruption; prevention of overeruption, etc.

do not restrict to NICE guidance. If tooth is removed for prophylactic reasons – please state.

Angulation: please indicate your assessment of the tooth's angulation in relation to the long axis of the second molar.

Eruption status: tooth is erupted if it has complete gingival collar around cervical margin of tooth. Tooth is partially erupted if gingival collar extends even minimally above or over crown of third molar.

DMFT score – calculate by counting each tooth that is filled, missing or carious.

Appendix II

Bacteriological profile of third molar related distal cervical caries of mandibular second molar teeth.

II. Introduction.

Radiographically, distal cervical caries of the Md2M develops at the distal amelo-cemental junction of the Md2M with a predilection for caries to penetrate through the cemental surface of the root into dentine (Figure II(i) a,b,c,d). The root surface of any tooth is more susceptible to caries as cementum and dentine are more vulnerable to demineralisation than enamel; enamel by contrast is protective and resistant to demineralisation. In the presence of a partially erupted MAMd3M or HORZMd3M, the root surface of the Md2M will become exposed to the oral environment due to the anatomical distortion of the normal relationship between the Md2M and the Md3M.

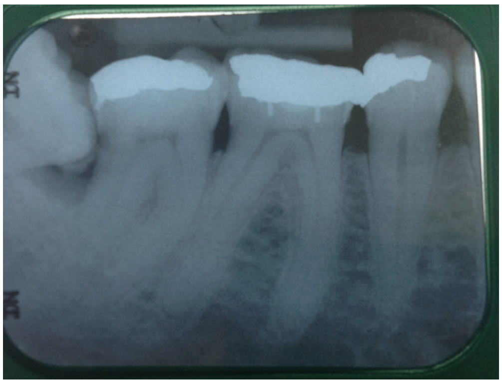
In the adolescent dentition, the developing Md3M will sit distally to the second molar within the follicular crypt and will appear to be develop in a mesio-angular position (Richardson, 1975). This mesio-angular orientation of the Md3M is normal at this stage and as the tooth begins its eruption process the position of the tooth will change due to differential root growth which should allow eruption into a vertical and functional position (Kjær, 2014). In a normal anatomical relationship, the alveolar wall of bone between a Md2M and a fully erupted Md3M is a vertical pillar of bone that forms the mesio-distal socket wall between the two teeth. This will normally extend vertically to just below the amelo-cemental junction between the two teeth and in disease-free teeth the inter-dental cervical bone is generally about 1mm below the amelo-cemental junction. This bone will also support the soft tissue of the gingivae and gingival papillae resulting in a shared circumferential collar of gingivae between each of the teeth.

The mesial impaction of the Md3M against the Md2M disrupts this normal anatomical relationship of the cervical bone between the two teeth. Comparison of the cervical bone level around both the Md3M and the Md2M demonstrates the cervical bone level around the Md3M appears to be at the normal level for the Md3M, however as the mesial cervical area of the Md3M is significantly lower than the cervical area of the Md2M the normal relationship is disrupted. As a consequence, the local anatomy is altered resulting in the loss of an intact gingival collar around the circumference of Md2M with the bone level distal to the Md2M being lower on the Md2M than would be expected. This gives the impression of distal bone loss which may be mistaken for periodontal disease and may give rise to a periodontal pocket. This pocket formation is not a result of periodontal disease but is a consequence of the failed eruption of the Md3M and the adaptation of the local anatomy to the impaction. This results in an acquired pocket rather than a pathological one, where the Md2M distal root surface below the level of the amelo-cemental junction will be exposed to the oral environment and colonisation with oral bacteria. This distal cervical area is not necessarily amenable to adequate oral hygiene in the form of tooth-brushing or interproximal cleaning and as a consequence disease can ensue either in the form of periodontal disease or DCC of the Md2M.

As with all carious cavities, DCC will begin with a small lesion and steadily progress to larger lesions with eventual penetration into the pulpal tissues (Figure II(i).). The distance from the distal root surface and the pulp chamber is much shorter than from the occlusal surface and because penetration of the caries is solely through cementum and dentine, DCC will tend to, once established, penetrate more rapidly into the pulp. Evidence has demonstrated that 40% of all Md2M with DCC associated with impacted Md3M are removed as a result (McArdle et al., 2016). The location of the disease compromises restoration, as the caries can transgress inferiorly down the root surface making restoration impossible. Early lesions can mimic radiographic burnout at the cervical margin which is caused by radiographic superimposition of the follicle of the Md3M and the Md2M giving a false impression of DCC (Littler, 1997).

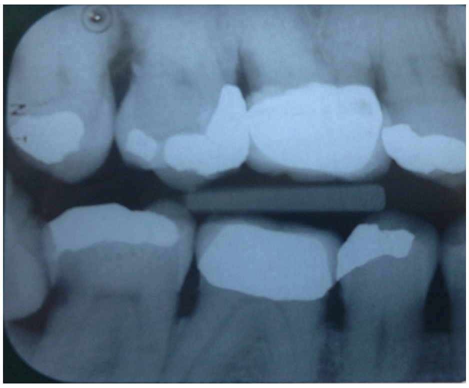
Figure II(i). Progression of Md2M DCC.

Figure IIi. (a) Early Md2M DCC



Legend: this image is a periapical radiograph demonstrating early DCC on the Md2M consequent to the retained and impacted Md3M. note the level of the interdental bone distal to the Md2M which is much lower than the mesial interdental bone. The bone level at the Md3M has approximated at the level of the amelo-cemental junction of the Md3M.

Figure IIi. (b) Progressing Md2M DCC.



Legend: this image is a bitewing radiograph of the same patient in figure IIi. (a). taken approximately 3 years later. It demonstrates progressing DCC present on the Md2M consequent to the retained and impacted Md3M.

Figure IIi. (c) DCC penetrating dental pulp.

Legend: this is a cropped image of a dental panoramic radiograph demonstrating DCC on the Md2M invading into the dental pulp of the Md2M consequent to the retained and impacted Md3M. Again, note the level of the interdental bone distal to the Md2M which is much lower than the mesial interdental bone. Even at this late stage the bone level at the Md3M maintains approximation at the level of the amelo-cemental junction of the Md3M.

Figure IIi.(d) Carious destruction of the second molar by DCC.

Legend: this photographic image is of the extracted Md2M in figure IIi. (c) demonstrating gross DCC on the Md2M consequent to the retained and impacted Md3M.

The nature of DCC of the Md2M has not been investigated from a bacteriological perspective. Radiographic observation of early Md2M DCC suggests that it originates at the amelo-cemental junction of the Md2M at the point of contact with the Md3M and selectively advances on the root surface. Md2M DCC would tend to be comparable with Class V buccal root surface caries found on patients with periodontal induced gingival recession or possibly root surface radiation caries as the lesion appears to start at the amelo-cemental junction.

II.i Aims

This study aims to look at the nature of the micro-flora of DCC lesions in an attempt to identify the spectrum of cariogenic bacteria contributing to DCC.

II.ii Ethics

(IRAS protocol, Patient information, ethics approval, and Research and Development approval letters are included at end of appendix II).

Local ethical committee advise was sought and as patients would be requested to provide tissue samples a full ethics approval application was undertaken. IRAS application was submitted (IRAS project ID 146708) and was assessed by the West of Scotland Research Ethics Committee. Research approval was granted (7th October 2015) by the Proportionate Review Sub-Committee (REC reference 15/WS/230) subject to local R&D approval which was granted (6th April 2016). Tissue samples were originally to be processed by the microbiology department of King's College London, however once all samples were collected, KCL were not in a position to process and microbiology support was sought elsewhere. The Blizzard Institute, QMUL, University of London was approached and agreed to process the samples, however this altered the original protocol and consequently an IRAS substantial amendment was applied for to reflect the change in the processing laboratory. Substantial amendment was accepted and approved by the West of Scotland Research Ethics Committee (27th September 2017) and samples could then be processed accordingly.

II.iii Methodology

Patients attending for Md3M removal due to Md2M DCC, where the Md2M was unrestorable, or when the patient elected to have the Md2M removed, were invited to participate in this study. The study involved the direct sampling of Md2M DCC lesions from the extracted tooth and the sampling of ipse-lateral and contra-lateral plaque from the same patients. Only patients who had Md2M extracted were enrolled as opposed to retained Md2M DCC as access to the carious cavity in a retained Md2M was deemed inaccessible for optimal curettage due to possible cross contamination. The aim was to recruit 15-20 patients for the study.

Although patients' treatment would remain as clinically indicated and planned, patients would be invited to consent to samples of plaque to be taken from the oral cavity and for their second molar tooth to be retained for caries sampling prior to standard disposal.

Mr. L. McArdle was chief investigator of the study and undertook overall study design; study protocol and patient information; R&D and research ethics application; recruitment and consent of patients, sample collection and storage. ***Professor W Wade and Dr Erica Prosdocimi at the Blizzard Institute undertook the processing of samples, sample analysis and provided a provisional results report.***

II.iv Protocol

Patients treatment planned and attending for removal of both the Md3M and Md2M where the indication for removal was Md2M DCC were invited to participate in this study. Patients had the study explained to them and given the opportunity to read through the study protocol and asked to sign a consent form if in agreement. Patients consented to plaque samples being taken and these were taken from the disto-buccal tooth surface between the Md2M and the Md3M that was being removed (ipsilateral side) and from the corresponding area of the contralateral Md2M. In addition, consent also included the temporary retention of the Md2M to allow sampling of the caries from the distal cervical cavity of the Md2M.

Plaque samples were taken using sterile paper points and placed in sealed cryogenic storage tubes and labelled accordingly. Once the Md2M was removed, caries was excavated from the distal cervical cavity with a sterile curette and similarly placed in a sealed labelled cryogenic storage tube. The cryogenic storage tubes were initially retained in a polystyrene container with dry ice. Within 30 minutes, samples were then transported to and stored in a cryogenic freezer at -85 degrees Celsius until all samples had been collected.

A total of 16 patients were enrolled into the study providing 3 samples per patient; sample 1 (ipsilateral plaque); sample 2 (contralateral plaque), both from the distal aspect of the second molar and sample 3 (DCC) from the distal cavity of the second molar tooth. Once all Md2M were sampled they were disposed of as per standard cross infection protocols. Plaque samples from patients C, D, E, and F were accidentally placed in the contrary plaque labelled cryogenic tubes. Ipsilateral plaque samples were placed into the cryogenic storage tubes marked for the contralateral plaque samples and vice versa. This was acknowledged and documented so that all samples were processed and reported accordingly.

II.v Sample analysis - method

Once all 48 samples (16 x 3 samples/patient) had been collected, they were transported to the Blizzard Institute, QMUL for analysis. Tissue samples were transported according to the Human Tissue Act protocols.

Samples were processed to permit analysis and identify the bacteriological profile of each of the plaque and carious samples. DNA was extracted from the samples by means of the GenElute DNA extraction kit (Sigma) with the addition of a pre-incubation with lysozyme to ensure lysis of Gram-positive bacteria. From each DNA extract, the variable regions V1 and V2 of the 16S rRNA gene were amplified by polymerase chain reactions (PCR) using the primers 27F-YM (AGAGTTTGATYMTGGCTCAG) and 338R-R (TGCTGCCTCCCGTAGRAGT). The primers incorporated the Illumina MiSeq adapters and sequence tags to achieve a double indexing system as determined by Kozich et al. 2013 (Kozich et al., 2013). Control PCR reactions were performed from two DNA extraction negatives and one mock community DNA (ZymoBIOMICS Microbial Community Standard, Cambridge Bioscience). A negative control without template DNA was included in each PCR plate. Amplicons were purified and normalised using four plates of SequalPrep Normalization Plate Kit (ThermoFisher Scientific), and a pool was obtained from each plate mixing 5 µl of each amplicon. The DNA in the four pools was quantified using the Picogreen Assay Reagent (ThermoFisher Scientific), and mixed in equimolar proportions. The sequencing was performed at the Bart's and The London Genome Center on the Illumina MiSeq machine, using a 2 x 250 flow cell for paired-end sequencing with 10% PhiX DNA 12.5 pM.

The output sequence pairs were filtered using the DADA2 R package according to the quality scores, to discard sequences with an expected error over 2 bp (base pairs). The first 10 bp of each sequence were trimmed; the forward and reverse sequences were truncated respectively at 250 and 200 bp length. The filtered sequences were analysed using the Mothur pipeline according to the standard operating procedure (SOP) available at https://www.mothur.org/wiki/MiSeq_SOP. (Kozich et al., 2013; Schloss et al., 2009). An additional pre-cluster step was performed to merge sequences with three or fewer bases differences. Sequence chimeras were removed from the analysis. Sequences were clustered into Operational Taxonomic Units (OTUs) at a sequence dissimilarity distance of 0.015 using an average neighbour algorithm and then classified using a Naïve Bayesian classifier implemented in Mothur with the Human Oral Microbiome Database reference dataset.

Alpha diversity indexes (and the Inverse Simpson's diversity index) were calculated by Mothur from each sample, by randomly subsampling 7099 sequences and averaging the results over 1000 replicas. The mean number of observed taxa and inverse Simpson's index in different sample types were compared by means of the Wilcoxon rank sum test.

Distance matrices were constructed comparing the beta diversity of samples from comparisons based on the Jaccard Index and thetaYC metric. Principal Coordinate Analysis (PCoA) and non-metric multidimensional scaling (nmds) analyses were performed and displayed as ordination plots. Analysis of Molecular Variance (AMOVA) comparisons between groups were performed to determine if there were statistical differences in the microbial composition of sample groups. Differentially abundant OTUs between groups of interest were identified using the LDA Effect Size (LEfSe) algorithm by Segata et al 2011 (Segata et al., 2011).

II.vi Results

A total of 850,193 sequences were available for analysis after quality filtering and chimera removal. The biofilm samples were sub-sampled to 7099 sequences for OTU-based comparisons. There were no significant differences in the richness (number of observed OTUs) of bacterial communities from different sample types (Wilcoxon) (Figure II(ii).). There was no difference in the diversity of the bacterial communities from the two plaque samples between ipsilateral and contralateral plaque samples or between contralateral plaque samples and the caries sample but the diversity of the caries samples was significantly lower than ipsilateral plaque samples ($p<0.05$, Wilcoxon) (Figure II(ii).).

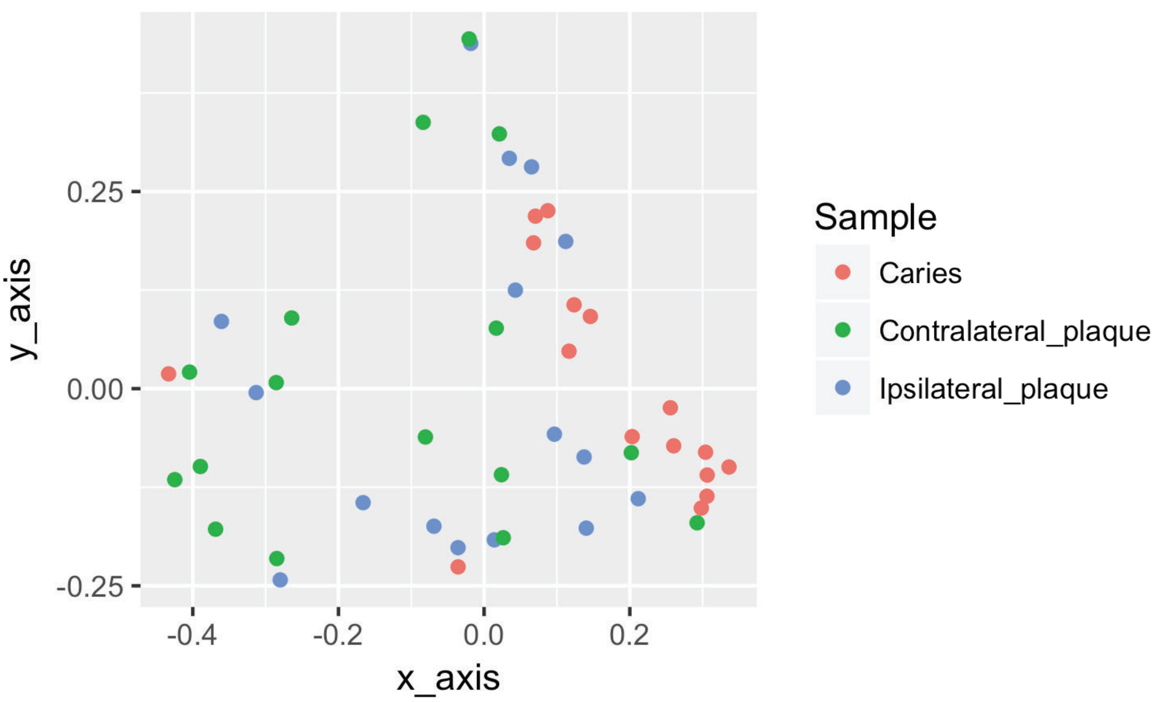
Figure II(ii). Richness and diversity of the sample microbiotas.

Sample group	n	Observed OTUs (sd)	Inverse Simpson (sd)
Ipsilateral plaque	16	326.0 (116.6)	26.9 (11.6)
Contralateral plaque	16	328.1 (107.5)	26.2 (13.2)
Caries	16	349.9 (81.2)	17.5 (7.8)

Legend: *Figure II(ii). demonstrates that there were no significant differences in the richness of bacterial communities from different sample types (i.e. the number of observed Operational Taxonomic Units) (Wilcoxon) There was no difference in the diversity of the bacterial communities from the two plaque samples between ipsilateral and contralateral plaque samples or between contralateral plaque samples and the caries sample but the diversity of the caries samples was significantly lower than ipsilateral plaque samples (p<0.05, Wilcoxon).*

A principal co-ordinates analysis (PCoA) plot based on thetaYC metric is shown in Figure II(iii). and shows the relationship between samples on the basis of their bacterial composition. It can be seen that, with the exception of two samples, the caries samples are clustered together to the right of the plot, suggesting that the bacteriological profiles of DCC were similar. This observation was confirmed further by analysis of molecular variance (AMOVA analysis) of the composition of the bacterial communities in the different plaque samples which showed them to be significantly different from the bacterial flora from the DCC samples. Pairwise comparisons found no difference between ipsilateral and contralateral plaque samples (plaque 1 and plaque 2 samples) but both were significantly different to the caries samples (plaque 1 p=0.007; plaque 2 p<0.001, significance threshold after Bonferroni correction: p<0.016).

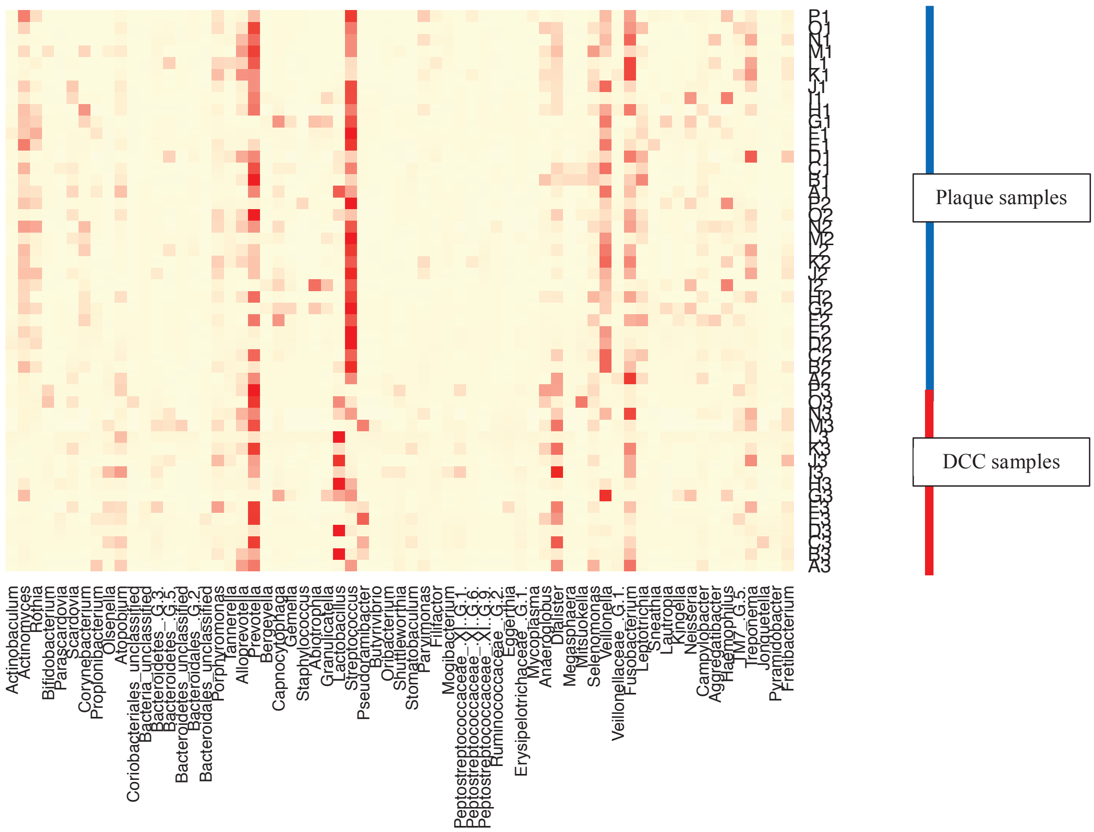
Figure II(iii). Principal coordinates analysis (PCoA) plots of sample bacterial community composition based on thetaYC metric.



Legend: *Figure II(iii). This figure demonstrates a principal co-ordinates analysis plot of the sample bacterial community composition. With the exception of two samples, the caries samples (red dots) are clustered together to the right of the plot, suggesting that the bacteriological profiles of DCC were similar.*

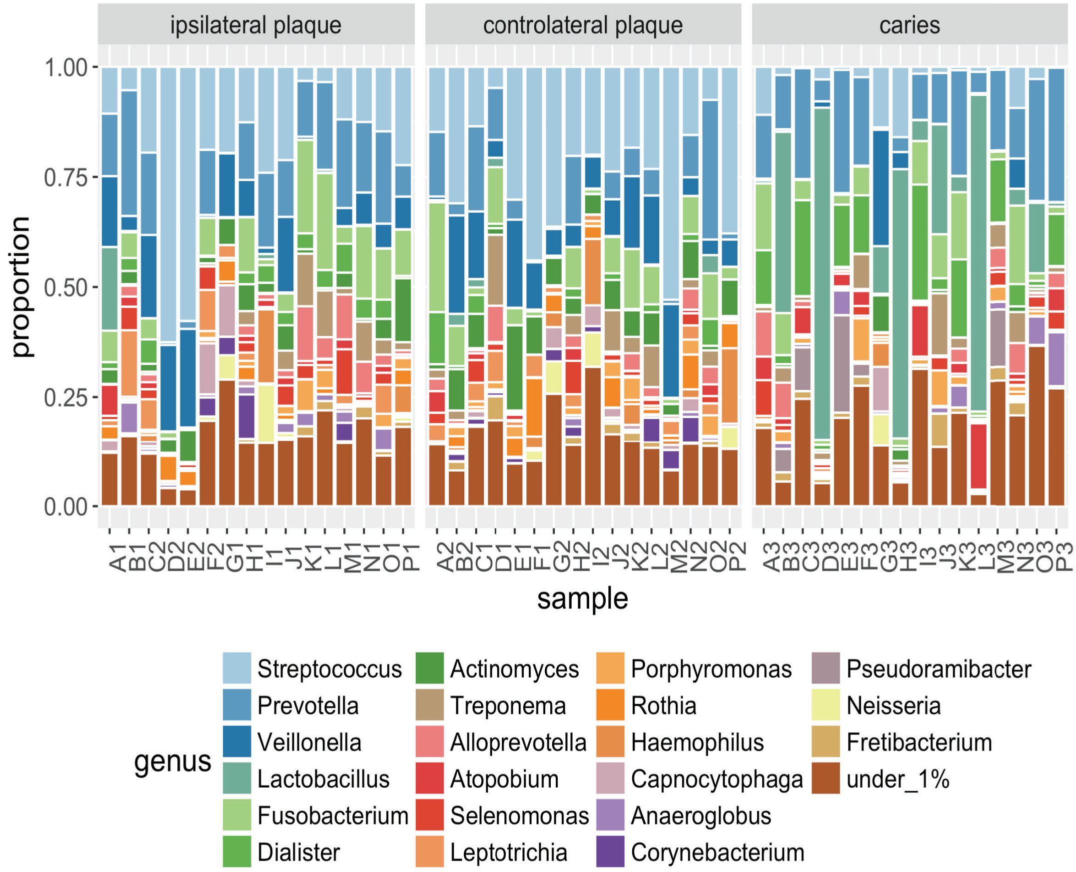
Figures II(iv) and II(v) show a heatmap and stacked bar chart, respectively, of the predominant genera found in the samples. The genera found were those typical of the oral microbiota but there were some differences between the plaque and caries samples. It can be seen that the relative abundance of *Dialister* and *Lactobacillus* species was increased in the caries samples while the proportions of *Actinomyces*, *Streptococcus* and *Veillonella* were decreased.

Figure II(iv). Heatmap showing relative abundance of bacterial genera in plaque and caries samples.



Legend: *Figure II(iv). This figure demonstrates a heatmap of the bacterial genera found within the samples. The genera found were those typical of the oral microbiota but there were some differences between the plaque and caries samples. It can be seen that the relative abundance of Dialister and Lactobacillus species was increased in the caries samples while the proportions of Actinomyces, Streptococcus and Veillonella were decreased.*

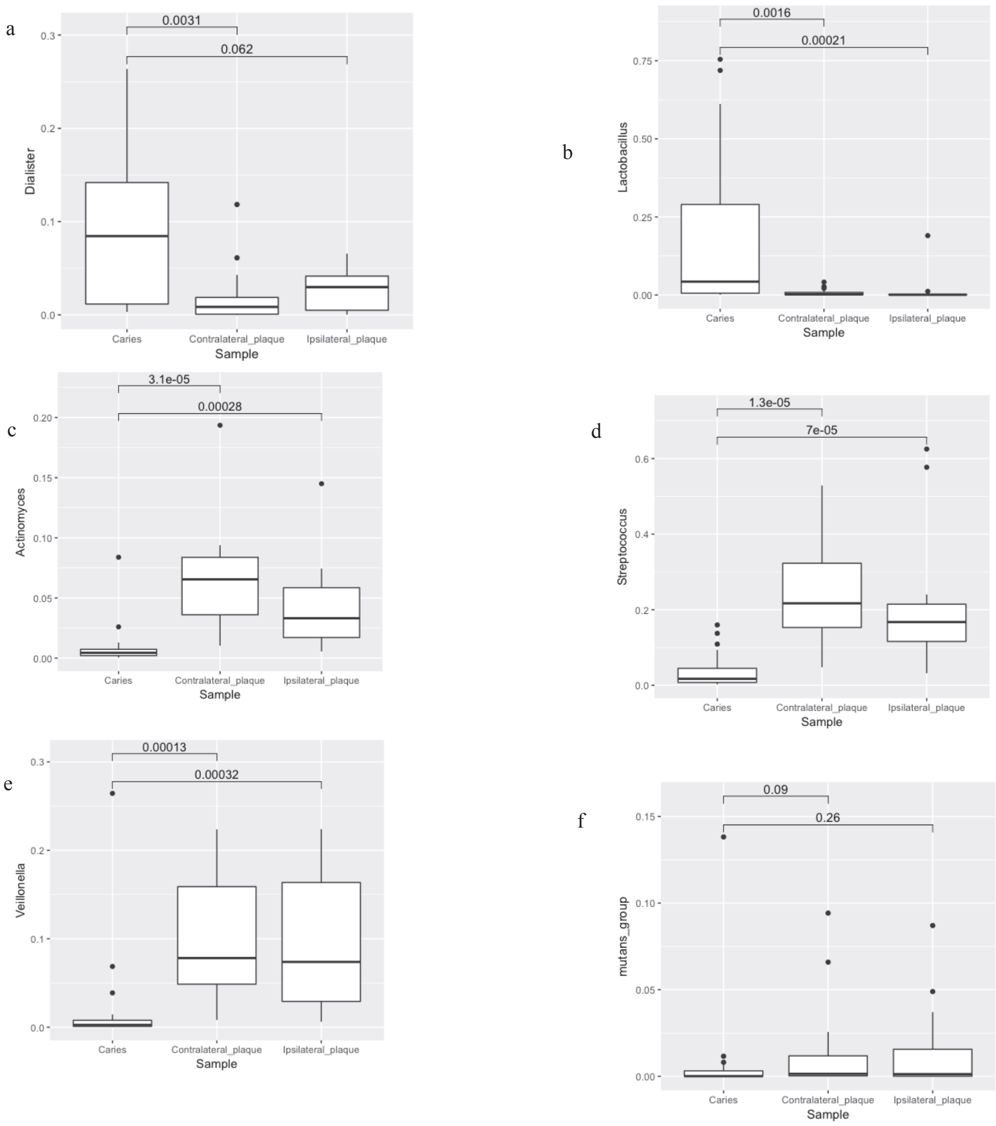
Figure II(v). Relative abundance of bacterial genera in plaque and caries samples.



***Legend:** Figure II(v). This figure demonstrates a stacked bar chart of the bacterial genera found within the samples. The genera found were those typical of the oral microbiota but there were some differences between the plaque and caries samples. It can be seen that the relative abundance of Dialister and Lactobacillus species (lighter green bars) was increased in the caries samples while the proportions of Actinomyces (darker green bar), Streptococcus and Veillonella (lighter blue bar) were decreased.*

Figure II(vi)a-e confirm these findings and show that the differences in relative abundance of these genera were statistically significant except for Dialister where the caries to ipsilateral plaque samples comparison was not significant (Wilcoxon test). Figure II(vi)f shows the relative abundance the mutans-group streptococci in the different sample types; levels were low and no differences in abundance were seen.

Figure II(vi). Box plots demonstrating selected genera and mutans-group streptococci as a proportion of the total microbiota.



Legend: *Figure II(vi). These box plots demonstrate the relative abundance of selected genera from plaque and caries samples. Genera Dialister and Lactobacillus are more abundant in caries as opposed to plaque samples. Actimomyces, Veillonella and Streptoccus show greater abundance in plaque than caries. Upper and lower edges of the boxes are the first and third quartiles; the line inside the box is the second quartile (median); individual dots are outliers. Statistical comparisons used the Wilcoxon test.*

Linear discriminant analysis Effect Size (LefSe) analysis was then performed to determine pattern recognition and to consider which species-level Operational Taxonomic Units were responsible for the significant differences seen. OTUs which were significantly over-represented in the caries samples are shown in figure II(vii). This confirmed the genus-level heat-map analysis in that multiple species of *Dialister* and *Lactobacillus* were caries-associated and also found that proportions of a number of other anaerobic species such as *Propionibacterium acidifaciens* and *Olsenella profusa* were raised.

Figure II(vii). OTUs significantly over-represented in caries samples.

OTU	Species	Linear Discriminant Analysis
011	*Dialister invisus*	4.1
013	*Prevotella denticola*	4.0
025	*Dialister pneumosintes*	3.7
038	*Lactobacillus vaginalis*	4.2
068	*Olsenella profusa*	3.7
072	*Lactobacillus casei*	3.8
090	*Propionibacterium acidifaciens*	3.4
105	*Eubacterium infirmum*	3.3
114	*Shuttleworthia satelles*	3.4
160	*Eggerthia catenaformis*	3.2
185	*Olsenella uli*	3.1
193	*Erysipelotrichaceae* G-1 HOT-905	3.0
246	*Veillonellaceae* G-1 HOT-132	2.7
409	*Dialister pneumosintes*	2.5
468	*Lactobacilli paracasei*	2.7
506	*Shuttleworthia satelles*	2.4
620	*Dialister invisus*	2.5
641	*Prevotella denticola*	2.4

Legend: *Figure II(vii). This table demonstrates the representation of bacterial genera* (*Operational Taxonomic Units*) *in the caries samples.*

II.vii Discussion

Dental caries is one of the most common diseases that humans experience and is the due to the decomposition of dental tissues from acid destruction (WHO, 2012). It is, in essence, a bacterial infection of the dental hard tissues, initially fueled by bacterial fermentation and metabolism of carbohydrates, such as sucrose, from food sources. The carbohydrate metabolism results in the production of acids which, in turn, cause demineralisation of enamel with consequent destruction of the dental tissues and eventual cavitation. Left untreated this eventually results in bacterial infection of the dental pulp and dental abscess formation (Loesche, 1996).

The external and internal surfaces of the human body are colonised and exist in symbiosis with commensal bacteria and other micro-organisms. This creates a biological ecosystem which is a normal physiological feature of all life. Commensal organisms live in equilibrium with each other and with the host’s immune system, however, disturbance of this equilibrium can result in opportunistic growth and proliferation of selective micro-organisms, which disrupts this equilibrium with the potential to cause disease.

Commensal bacteria within the oral cavity colonise the surface of teeth and form a bacterial biofilm that is commonly referred to as dental plaque. Dental plaque is a matrix of bacteria and polysaccharides and this ecosystem promotes the further growth and proliferation of bacteria. It is estimated that there are more than 600-1000 bacterial species that colonise the oral cavity however not all are implicated in dental disease (ten Cate, 2006).

Typical dental plaque has been shown to include a variety of bacterial groups the majority of which are *Streptococci* group but also *Actinomyces, Veillonella and Prevotella*. In this study, the samples of plaque from both ipsilateral and contralateral supra-gingival tooth surfaces are similar in composition with each other demonstrating substantial levels of gram-positive *Streptococci*, along with *Actinomyces* and gram-negative *Veillonella*. In contrast levels of *Lactobacillus* tend to be absent or minimal in both though studies demonstrate *Lactobacillus* group to be a feature of plaque. Plaque samples from this study tend to be typical of dental plaque and similar to other studies (Nyvad, 1987; ten Cate, 2006).

Saliva provides the initial nutritional substrate for supra-gingival plaque though carbohydrates within the diet act as an additional nutritional source. Streptococci break down salivary glycoproteins and produce lactate which in turn is an energy source for *Veillonella* (Loesche, 1996).

Streptococcal mutans group of bacteria are the main dominant bacterial initiator for dental caries. *S. mutans* have a diverse ability to efficiently metabolise sucrose. Sucrose can be metabolised into fructose and glucose then subsequently be metabolised via the glycolytic pathway which results in lactic acid production. In addition, *s. mutans* can form complex glucose polymers (glucans) which facilitates adhesion of *S. mutans* to the enamel surface and plaque formation. Other bacterial groups such as *Lactobacillus* are also associated with acid production in plaque and early caries lesions, however, *S.mutans* is the most efficient bacteria for the metabolism and utilisation of sucrose and as a result is becomes the most dominant species in plaque. Lactic acid production causes a reduction in pH within the plaque and as *S. mutans* and Lactobacillus are aciduric in nature, not only do they produce acid but are more resistant to the harmful effects of low pH than other bacteria which in turns allows them to be more proliferative and successful in eliminating and suppressing other oral commensals in dental plaque.

The bacteriological profile of dental caries changes with the progression of the carious lesion from early carious through to deeper lesions that penetrate into the dentine and pulpal tissues (Kianoush et al., 2014; Martin et al., 2002). In early dental caries lesions, *mutans-group streptococci* and *lactobacilli* tend to be the predominant bacteria present, however as the carious lesion progresses into dentine there is a transition in bacterial population from these facultative gram-positive bacteria to an anaerobic bacterial population (Kianoush et al., 2014). The DCC samples taken from the Md2M were unrestorable and consequently caries lesions were deep and extensive. DCC samples had reduced levels of *Streptococcus*, *Actinomyces* and *Veillonella* with increased levels of obligate anaerobes such as *Dialister*, suggesting a substantial environmental change from the tooth surfaces.

DCC is seen on the distal root surface of the second molar. Root surface caries is a common finding in older patient groups due to the fact that age related gingival recession and periodontal disease results in exposure of the dentine root surfaces. Root surface caries predominates in the buccal root surface although it can affect any exposed root surface. In addition, loss of manual dexterity due to age related arthritic conditions may play a factor in effective dental hygiene. DCC is generally seen in younger patient groups as opposed to the older patients that buccal root surface caries would affect, however the location of the carious lesion is not dissimilar to buccal root surface in terms of its proximity on the root form though present on the distal surface of the tooth rather than the buccal surface.

For root caries, studies have demonstrated that the bacteria implicated in initial caries formation include, *s. mutans, lactobacillus* and *actinomyces,* with more established root caries lesions also demonstrating a predominance of *s. mutans, lactobacillus, actinomyces but also prevotella, atopobium* and olsenella species (Preza et al., 2008). These findings are not dissimilar to the bacterial populations of the DCC samples from this study. It would be anticipated that coronal caries would be dissimilar to root caries due to the location of the caries on the tooth. Literature suggests that coronal caries is *mutans-group streptococci, lactobacilli* and other aciduric bacteria, however root caries is more similar to coronal caries than once thought with *Actinomyces* being implicated (Bowden, 1990).

II.viii Conclusion

The findings for the DCC samples here suggests that deep lesions have been formed with extensive dentine penetration. The lesions are thus anaerobic and the nutrients for the bacteria come from the pulp leaking through the dentine. The fact that caries was the cause of the lesions is shown by the persistence of *lactobacilli*, as previously reported. It has been demonstrated from studies of deep advancing carious lesions that *Propionibacterium*, *Olsenella,* and *Lactobacillus* were the predominant species in deep dentinal caries samples, suggesting that this deeper carious habitat favours obligate anaerobes with a primarily proteolytic metabolism (Munson et al., 2004). On the basis of the results of this study, the composition of the caries samples appears to most closely resemble that previously reported in carious lesions with substantial penetration into dentine (Munson et al., 2004).

II.I IRAS protocol

Guy's and St Thomas' NHS
NHS Foundation Trust

It is a requirement of Good Clinical Practice (GCP) and the Research Governance Framework for Health & Social Care 2005, that all research projects have a scientifically sound and ethically valid protocol.

The protocol is the starting point of any high quality research and all research studies must be conducted according to the protocol. A protocol provides written evidence for the necessity and feasibility of a study, as well as giving a detailed plan of investigation.

This document is to be submitted for approval to a Research Ethics Committee. This allows the ethical and peer review processes to validate the scientific and ethical considerations of the study. The guidance detailed below is for all research studies of Non Investigational Medicinal Products (Non CTIMPs) with the exception of those testing a device.

PROTOCOL TITLE:
Bacteriological profile of third molar related distal cervical caries.

This case-series study wishes to assess the bacteria present in decayed second molar teeth. Teeth that are extracted are normally disposed of as clinical waste. We wish to retain these specific teeth and sample the dental decay to identify the bacteria responsible for that decay. This will be achieved through microbiology laboratory testing of the material. We aim to identify the types and proportion of bacteria responsible for the decay and compare it with other known caries bacterial profiles. Once the decay is sampled these teeth will be disposed of in the normal way, as clinical waste. We will also collect as sample of dental plaque from the contra-lateral side of the jaw. This sample of dental plaque will be assessed in a similar way and used as a comparative control sample.

Sponsor

Name: Keith Brennan

Address: rm 1.8 Hodgkin Building, Gu's campus

Telephone: 020 7848 6960

Fax:

Email: keith.brennan@kcl.ac.uk

Chief Investigator
Name: Mr Louis McArdle

Address: Dept of Oral Surgery, floor 23 Guy's Tower wing. Guy's Hospital

Telephone: 020 7188 4345

Fax:

Email: louis.mcardle@kcl.ac.uk

Name and address of Co-Investigator(s), Statistician, Laboratories etc
Name: Professor Fraser McDonald

Address: Dept of Orthodontics, floor 26 Guy's Tower wing, Guy's Hospital

Telephone:

Fax:

Email: fraser.mcdonald@kcl.ac.uk

Name: Dr Kenneth Bruce ***Address: Dept of Microbiology KCL*** ***Telephone:*** ***Fax:*** ***Email: kenneth.bruce@kcl.ac.uk***	***Name: Professor William Wade*** ***Address: Dept of Microbiology QMUL*** ***Telephone:*** ***Fax:*** ***Email: william.wade@qmul.ac.uk***

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Study Synopsis

Title	Bacteriological profile of third molar related distal cervical caries in second molar teeth
Protocol Short Title/Acronym	Md2M DCC
Protocol Version number and Date	Protocol version 2 (7/4/17)
Study Phase if not mentioned in title	Phase 1
Is the study a Pilot?	yes
Study Hypothesis	identify bacterial flora of tooth decay
Study Duration	6months
Methodology	Stand alone case-series of clinical specimens
Sponsor name	KCL
Chief Investigator	Mr Louis McArdle
REC number	IRAS 146708 15/LO/1279
Medical condition or disease under investigation	Dental Caries
Purpose of clinical trial	Assess bacteriological profile of caries
Primary objective	Assess bacteriological profile of caries
Secondary objective (s)	n/a
Number of Subjects/Patients	15-20 maximum
Trial Design	Case series
Endpoints	Completion of 15-20 samples
Main Inclusion Criteria	Patients requiring removal of second molar teeth

Glossary of Terms and Abbreviations

AE	Adverse Event
AR	Adverse Reaction
ASR	Annual Safety Report
CA	Competent Authority
CI	Chief Investigator
CRF	Case Report Form
CRO	Contract Research Organisation
DMC	Data Monitoring Committee
EC	European Commission
GAfREC	Governance Arrangements for NHS Research Ethics Committees
ICF	Informed Consent Form
ISRCTN	International Standard Randomised Controlled Trial Number
MA	Marketing Authorisation
MS	Member State
Main REC	Main Research Ethics Committee
NHS R&D	National Health Service Research & Development
PI	Principle Investigator
QA	Quality Assurance
QC	Quality Control
Participant	An individual who takes part in a clinical trial
RCT	Randomised Controlled Trial
REC	Research Ethics Committee
SAE	Serious Adverse Event
SDV	Source Document Verification
SOP	Standard Operating Procedure
SSA	Site Specific Assessment
TMG	Trial Management Group
TSC	Trial Steering Committee

1. Introduction

Distal cervical caries (DCC) is a form of tooth decay that forms on the distal aspect of the mandibular second molar tooth as a consequence of third molar impaction. This type of dental caries forms at the cervical margin and initially forms on the root surface. The bacteriological profile of this type of caries is unknown. We wish to sample this type of caries to ascertain if the bacteria responsible for the root caries on the second molar teeth are the same or dissimilar to bacteria that cause other forms dental caries.

On occasions the second molar tooth is removed as part of the patient's treatment plan. This is because the patient has elected to have this tooth removed or no other treatment is appropriate. Teeth once removed are disposed of as clinical waste. This pilot study proposes to retain these teeth for bacteriological sampling and assessment of the caries for the bacteriological profile by DNA-DNA hybridisation technique. Once sampled the teeth will be disposed of as clinical waste in the conventional approved way.

Patient's treatment will not be altered in any way. There are no risks to patient safety and no benefits to patient care.

2 Trial Objectives, Design and Statistics

2.1. Trial Objectives

- Primary Objective - Which types of bacteria are present in dental decay lesions from the sample group and the proportions of the types of bacteria present in these carious lesions. How do these compare with known caries bacterial profiles as reported in the literature and where paired samples are taken from each other.

- Primary End Point collection and assessment of 20 clinical samples

2.2 Trial Design & Flowchart

- **Removal of decayed tooth**
- **Sampling of dental caries in extracted tooth, sampling of dental plaque from same patient from secondary site in mouth.**
- **Processing of decay/sample.**
- **Identification/analysis of bacteria present in tooth decay from sampled teeth**
- **Disposal of teeth/sample**

2.3 Trial Flowchart

1st appointment - patent attends for consultation, treatment plan agreed, treatment consent taken. If patient & treatment fulfils inclusion criteria then patient approached regarding study and retention of tooth for study.

2nd appointment – patient attends for treatment, consent confirmed, treatment undertaken, patient discharged. Tooth/specimen retained for study.

2.4 Trial Statistics

Statistical analysis of data is not relevant to this study and collected data will not be subject to statistical analysis

3. Sample Size, Selection and Withdrawal of Subjects

maximum 20. Sample from 20 suitable patients over 6month period. Patients will be identified from outpatient consultant clinics.

Inclusion criteria – any patients attending for removal of mandibular second molar teeth that demonstrate distal cervical caries.

Exclusion criteria – all other patients. Vulnerable groups who cannot give informed consent. Patients who are known carries of blood borne viruses.

3.1 Inclusion Criteria

Include:

- Patients requiring the removal of a mandibular second molar tooth due to distal cervical caries.
- Patients who have the capacity to give informed consent to the retention of their tooth for investigation.

3.2 Exclusion Criteria

Patients who do not fulfill the inclusion criteria. all other patients. Vulnerable groups who cannot give informed consent. Patients who are known carries of blood borne viruses.

3.3 Criteria for Premature Withdrawal

Withdrawal of consent

4. Study procedures

Informed Consent Procedures

Patients who require the removal of their mandibular second molar teeth due to distal cervical caries will be advised of the research project. They will be informed of the nature of the project and given the information and consent form to read and consider. Patients willing to donate their tooth for the purposes of the research will be asked to sign the consent form and treatment will proceed as normal.

Patients who do not wish to donate their tooth will have their treatment undertaken as normal.

4.1 Screening Procedures - not applicable

4.2 Randomisation Procedures - not applicable

4.3 Schedule of Treatment for each visit

patient's treatment will not be altered – only change in treatment management is that teeth removed are sampled and then disposed as opposed to direct disposal.

4.4 Follow up Procedures (if applicable)

no follow up required

4.5 Radiology Assessments

Standard radiographic examination to aid diagnosis and treatment planning. No exceptional nor additional investigations required as part of this project.

4.6 End of Study Definition

On completion of 20 tooth donations/specimens

5. Laboratories

Sampling of tooth decay from extracted tooth and subsequent dna-dna hybridization analysis of bacteria to identify bacterial flora. No human DNA analysis will be undertaken.

5.1 Central/Local Laboratories

microbiology. DNA- DNA hybridisation

5.2 Sample Collection/Labelling/Logging

Samples will be fully anonymised. Samples will be collected and retained in sample pots labelled in numerical order and logged for identification purposes. These will be stored cryogenically within 1 hour of sampling. Once the data set has been reached they will be cryogenically transferred for processing and assessment.

5.3 Sample Analysis Procedures

DNA-DNA hybridization of dental caries sampled from extracted tooth and from control sample of same patients

5.4 Sample Storage Procedures samples will be cryogenically stored at -800c until processing and assessment – after assessment they will be disposed of as clinical waste in the normal manner.

5.5 Data Recording/Reporting

Data will be recorded and stored on KCL computer systems. Password protected, on Excel software.

5.6 Sample Receipt/Chain of Custody/Accountability

Samples will be hand delivered by chief investigator to laboratory staff. Sample Inventory and anonomysed sample records will be recorded and retained. Sample will be processed and appropriately disposed of. Once disposed, disposal will be recorded.

5.7 Sample Transfer

In the study, teeth will be retained from patients in accordance with the patient consent form and patient information sheet and shall include all tissue samples or other biological materials and any derivatives, portions, progeny or improvements as well as all patient information and documentation supplied in relation to them. Further, the custodian of the Materials and use the Materials for the Study only. For the avoidance of doubt Recipient shall only use the Material in accordance with the consent provided by the Study Donors (if applicable) and shall always use the Materials with dignity and respect and shall always use good laboratory practice in handling Materials

The teeth and dental plaque will be sampled by Mr Louis McArdle and stored in an appropriately designed container. Samples will then be cryogenically stored. The teeth will subsequently be disposed of in the normal manner as clinical waste and in accordance with the Human Tissue Act 2004. Once 20 cases have been sampled, the samples will be cryogenically transferred to either *Dr Ken Bruce, KCL or Professor William Wade QMUL* for analysis. Bacterial DNA will to be extracted from the caries to identify bacteria.

Dr Ken Bruce, KCL, or Professor William Wade will process, and dispose of the samples in accordance with all applicable legal and regulatory requirements, including the Human Tissue Act 2004 and any amendments thereto. While Provider uses reasonable endeavours to ensure the quality of the Materials, the Materials are provided 'as is' and it makes no representation and gives no warranty or undertaking in relation to the Materials, including but not limited to its safety, fitness for purpose or use of any kind.

The teeth will not be transferred to any party not identified in this protocol and are not to be processed and/or transferred other than in accordance with the patients' consent. After ethics approval for the study has expired, the teeth will be disposed of in accordance with the Human Tissue Act 2004, and any amendments thereto, or transferred to a licensed tissue bank.

6. Assessment of Safety

not applicable – no safety issues

6.1 Ethics Reporting

no SAE possible

7. Trial Steering Committee (if applicable)
none applicable

8. Ethics & Regulatory Approvals
GSTT REC

9. Data Handling
Confidentiality

No patient identifiable date will be collected or retained. Samples will be given a sequential numerical code 1 through 20

Case Report Form - Not applicable

Record Retention and Archiving

Consent forms will be retained in patient's clinical notes

Compliance

The CI will ensure that the trial is conducted in compliance with the principles of the Declaration of Helsinki (1996), and in accordance with all applicable regulatory requirements including but not limited to the Research Governance Framework, Trust and Research Office policies and procedures and any subsequent amendments.

Clinical Governance Issues

Audit and Inspection

Auditing: Definition "A systematic and independent examination of trial related activities and documents to determine whether the evaluated trial related activities were conducted, and the data were recorded, analysed and accurately reported according to the protocol, sponsor's standard operating procedures (SOPs), Good Clinical Practice (GCP), and the applicable regulatory requirement(s)."

A study may be identified for audit by any method listed below:

- project may be identified via the risk assessment process.
- An individual investigator or department may request an audit.
- A project may be identified via an allegation of research misconduct or fraud or a suspected breach of regulations.
- Projects may be selected at random. The Department of Health states that Trusts should be auditing a minimum of 10% of all research projects.
- Projects may be randomly selected for audit by an external organisation.
- Internal audits will be conducted by a sponsor's representative

Non-Compliance

(A noted systematic lack of both the CI and the study staff adhering to SOPs/protocol/ICH-GCP, which leads to prolonged collection of deviations, breaches or suspected fraud.) These non-compliances may be captured from a variety of different sources including monitoring visits, CRFs, communications and updates. The sponsor will maintain a log of the non-compliances to ascertain if there are any trends developing which to be escalated. The sponsor will assess the non-compliances and action a timeframe in which they need to be dealt with. Each action will be given a different timeframe dependent on the severity. If the actions are not dealt with accordingly, the R&D Office will agree an appropriate action, including an on-site audit.

10. Finance and Publication Policy

Funding of £3,000 allocated from chief investigators KCL Special Fund NPS9104. Funding managed by chief investigator.

Name and address of funder Funded through Kings NPS9104 (McArdle Special Fund)

Name: Mr Louis Wm McArdle

Address: Dept of Oral Surgery

Telephone: 07885 137050

Fax:

Email: louis.mcardle@kcl.ac.uk

Data will be published in peer-reviewed journals as appropriate and included in PhD thesis.

Appendix (i) – Information with regards to Safety Reporting in Non-CTIMP Research

	Who	When	How	To Whom
SAE	Chief Investigator	-Report to Sponsor within 24 hours of learning of the event -Report to the MREC within 15 days of learning of the event	SAE Report form for Non-CTIMPs, available from NRES website.	Sponsor and MREC
Urgent Safety Measures	Chief Investigator	Contact the Sponsor and MREC Immediately Within 3 days	By phone Substantial amendment form giving notice in writing setting out the reasons for the urgent safety measures and the plan for future action.	Main REC and Sponsor Main REC with a copy also sent to the sponsor. The MREC will acknowledge this within 30 days of receipt.
Progress Reports	Chief Investigator	Annually (starting 12 months after the date of favourable opinion)	Annual Progress Report Form (non-CTIMPs) available from the NRES website	Main REC
Declaration of the conclusion or early termination of the study	Chief Investigator	Within 90 days (conclusion) Within 15 days (early termination) The end of study should be defined in the protocol	End of Study Declaration form available from the NRES website	Main REC with a copy to be sent to the sponsor
Summary of final Report	Chief Investigator	Within one year of conclusion of the Research	No Standard Format However, the following Information should be included:- Where the study has met its objectives, the main findings and arrangements for publication or dissemination including feedback to participants	Main REC with a copy to be sent to the sponsor

Appendix II.II – Patient information and consent

KING'S College LONDON

Guy's and St Thomas' NHS

NHS Foundation Trust

Third Molar/Distal Cervical Caries study.

Patient information sheet and consent form

Dear Patient,

Patient label

We are undertaking a research study looking at the types of bacteria that cause tooth decay in the types of teeth that we are taking out for you. Normally when a tooth is removed it is disposed of as clinical waste as directed by the Human Tissue Act (2004). As part of this study we would like to keep your tooth for research purposes so that we can test it to identify the types of bacteria that may be contributing to the tooth decay in your tooth. In addition, we would like to take a small smear of dental plaque from another tooth in your mouth to compare.

What does taking part in the study involve?

Your treatment will be no different – you will still have your tooth/teeth removed in the normal manner. We would also wish to take a small smear of dental plaque from the surface of another tooth to look at the bacteria present. This will involve wiping another tooth clean with a sterile swab. Your tooth & dental plaque sample will then be processed to identify the types of bacteria present. Once it has been processed it will be disposed of in the normal manner as directed by the Human Tissue Act (2004).

Do I have to take part in this study?

No, it is completely up to you. If you do not wish your tooth to be used in this way then it will be disposed of in the normal manner once it has been extracted. Donating your tooth and dental plaque sample will not affect your treatment in anyway.

Are there any risks from participating in this study?

There are no additional risks to you as a patient from donating your tooth and dental plaque sample. Your treatment will be the same.

Will the information gained from the study be identifiable to me?

The samples and data that we obtain will not include any of your personal information. The data obtained will be stored on a computer using a unique identification number. A single table file will link this unique identification number with your NHS record number and this will be stored on a separate password protected location. Only the principal investigator will have access to this file.

What if there is a problem?

If you have a concern about any aspect of this study, you should ask to speak to the researchers who will do their best to answer your questions. Please contact: Principle Investigator, Mr L. McArdle, email: louis.mcardle@kcl.ac.uk or tel: 020 7188 4345.

If you have a complaint, you should talk to your research doctor who will do their best to answer your questions. If you remain unhappy, you may be able to make a formal complaint through the NHS complaints procedure. Details can be obtained through the Guy's and St Thomas' Patient Advisory Liaison Service (PALS) on 0207 1887188, address: PALS, KIC, Ground floor, north wing, St Thomas' Hospital, Westminster Bridge Road, London, SE1 7EH .

This trial is co-sponsored by King's College London and Guy's and St Thomas' NHS Foundation Trust. The sponsors will at all times maintain adequate insurance in relation to the study independently. Kings College London, through its own professional indemnity (Clinical Trials) and no fault compensation and the Trust having a duty of care to patients via NHS indemnity cover, in respect of any claims arising as a result of clinical negligence by its employees, brought by or on behalf of a study patient but you may have to pay your legal costs. The normal National Health Service complaints mechanisms will still be available to you (if appropriate).

What do I do next?

If you wish to give consent for your tooth & sample to be used in this way we would be grateful if you could sign the consent form below. One copy will be stored in your patient file and you will be given a copy.

Please initial box

1. I confirm that I have read this information sheet and that I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.

2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my medical care or legal rights being affected.

3. I understand that the information collected about me may be used to support other research in the future, and may be shared anonymously with other researchers.

4. I agree to take part in the above study.

____________________	____________________	____________________
Name of Participant	Date	Signature
____________________	____________________	____________________
Name of Person taking consent	Date	Signature

II.III Md2M DCC bacteriological samples database.

Md2M DCC Bacteriological Samples Database

sample ID	date collected	Ipsi-lateral plaque	Contra-lateral plaque	DCC sample
A	20/05/2016	A1	A2	A3
B	27/05/2016	B1	B2	B3
C	23/06/2016	C2	C1	C3
D	22/07/2016	D2	D1	D3
E	01/08/2016	E2	E1	E3
F	08/08/2016	F2	F1	F3
G	09/08/2016	G1	G2	G3
H	12/08/2016	H1	H2	H3
I	16/08/2016	I1	I2	I3
J	21/10/2016	J1	J2	J3
K	04/11/2016	K1	K2	K3
L	14/11/2016	L1	L2	L3
M	24/11/2016	M1	M2	M3
N	25/11/2016	N1	N2	N3
O	20/12/2016	O1	O2	O3
P	24/02/2017	P1	P2	P3

WoSRES
West of Scotland Research Ethics Service

NHS
Greater Glasgow and Clyde

West of Scotland REC 5
Ground Floor - Tennent Building
Western Infirmary
38 Church Street
Glasgow
G11 6NT

Mr Louis W. McArdle
Department of Oral Surgery,
KCL Dental Institute
Guy's Hospital
Great Maze Pond
London
SE1 9RT

Date 07 October 2015

Direct line 0141 211 2102
E-mail WoSREC5@ggc.scot.nhs.uk

Dear Mr McArdle

Study title:	**Bacteriological profile of third molar related distal cervical caries in second molar teeth.**
REC reference:	**15/WS/0230**
Protocol number:	**n/a**
IRAS project ID:	**146708**

The Proportionate Review Sub-committee of the West of Scotland REC 5 reviewed the above application on 07 October 2015.

We plan to publish your research summary wording for the above study on the HRA website, together with your contact details. Publication will be no earlier than three months from the date of this favourable opinion letter. The expectation is that this information will be published for all studies that receive an ethical opinion but should you wish to provide a substitute contact point, wish to make a request to defer, or require further information, please contact the REC Manager Mrs Sharon Macgregor, WoSREC5@ggc.scot.nhs.uk. Under very limited circumstances (e.g. for student research which has received an unfavourable opinion), it may be possible to grant an exemption to the publication of the study.

Ethical opinion

On behalf of the Committee, the sub-committee gave a favourable ethical opinion of the above research on the basis described in the application form, protocol and supporting documentation, subject to the conditions specified below.

Conditions of the favourable opinion

The favourable opinion is subject to the following conditions being met prior to the start of the study.

<u>Management permission or approval must be obtained from each host organisation prior to the start of the study at the site concerned</u>.

WoSRES

West of Scotland Research Ethics Service

NHS Greater Glasgow and Clyde

West of Scotland REC 5
West of Scotland Research Ethics Service
West Glasgow Ambulatory Care Hospital
Dalnair Street
Glasgow
G3 8SJ

Mr Louis W. McArdle
Department of Oral Surgery,
KCL Dental Institute, Guy's Hospital, Great Maze Pond
London
SE1 9RT

Date 27 September 2017

Direct line 0141 232 1809
E-mail WoSREC5@ggc.scot.nhs.uk

Dear Mr McArdle

Study title:	**Bacteriological profile of third molar related distal cervical caries in second molar teeth.**
REC reference:	**15/WS/0230**
Protocol number:	**n/a**
Amendment number:	**1 (REC Ref AM05 SA)**
Amendment date:	**07 April 2017**
IRAS project ID:	**146708**

The above amendment was reviewed by the Sub-Committee in correspondence.

Ethical opinion

The members of the Committee taking part in the review gave a favourable ethical opinion of the amendment on the basis described in the notice of amendment form and supporting documentation.

Approved documents

The documents reviewed and approved at the meeting were:

Document	*Version*	*Date*
Notice of Substantial Amendment (non-CTIMP)	1 (REC Ref AM05 SA)	07 April 2017
Research protocol or project proposal	2	07 April 2017

Membership of the Committee

The members of the Committee who took part in the review are listed on the attached sheet.

Working with NHS Care Organisations

Appendix III

Peer reviewed publications from the data of this thesis

McArdle LW, Renton T. **The effects of NICE guidelines on the management of third molar teeth.** British Dental Journal. 2012; **213**(5): 1-7.

McArdle LW, McDonald F, Jones J. **Distal cervical caries in the mandibular second molar: and indication for the prophylactic removal of the third molar? Update.** British Journal of Oral and Maxillofacial Surgery. 2014; **52**: 185-189

McArdle LW, Patel N, Jones J, McDonald F**. The mesially impacted mandibular third molar: the incidence and consequences of distal cervical caries in the mandibular second molar.** The Surgeon. Journal of the Royal Colleges of Surgeons of Edinburgh and Ireland 2016; **16**(2):67-73.

McArdle, LW, Andiappan M, Khan I, Jones J, and McDonald F. **Diseases associated with mandibular third molar teeth**. British Dental Journal 2018; **224**(6): 434-440.

McArdle LW, Jones J, McDonald F. **Characteristics of disease related to mesio-angular mandibular third molar teeth.** British Journal of Oral and Maxillofacial Surgery 2019; **57**:306-311.

The effects of NICE guidelines on the management of third molar teeth

L. W. McArdle[1] and T. Renton[2]

IN BRIEF

- Highlights that third molar removal is as common now as it was before the introduction of clinical guidelines.
- Informs that NICE guidelines have altered the dynamics of third molar management with patients on average being older.
- Stresses that dental caries associated with third molars has escalated by over 200% in a ten-year period.
- Suggests NICE guidelines may be flawed and require review.

Background Third molar surgery (TMS) is probably one of the most commonly performed surgical procedures undertaken in the NHS. In 2000, the National Institute of Clinical Excellence (NICE) introduced guidelines relating to TMS. These recommended against the prophylactic removal of third molars and listed specific clinical indications for surgery. The impact of these guidelines has not been fully evaluated and this research hopes to focus the effect of these guidelines over the last ten years. **Methods** Using data obtained from a variety of NHS databases such as HES (Eng & Wales), the NHSBSA and data from NHS Scotland, we looked at the age range of patients requiring third molar removal and the number of patients having third molars removed in both primary and secondary care environments from 1989 to 2009. In addition we looked at the clinical indications for TMS activity in secondary care. **Findings** The mean age of patients increased from 25 years in 2000 to 32 years in 2010, with the modal (most common) age increasing from 26 to 29 years. After the introduction of clinical guidelines the number of patients requiring third molar removal in secondary care dropped by over 30%, however, since 2003 the number of patients has risen by 97%. There is also a significant increase in caries as an indication for third molar removal. **Conclusions** More patients are requiring third molar removal with an increasing number of patients having caries related to their third molars. Patients are, on average, older confirming that the removal of third molars is shifting from a young adult population group to an older adult population group. NICE guidelines did appear to have contributed to a fall in the volume of third molars removed within the NHS post 2000. However, concluding that this reduction demonstrates the success of NICE's guidance would be a premature assumption. The number of patients now requiring third molar removal is comparable to that of the mid 1990s. NICE has influenced the management of patients with third molars but this has not resulted in any reduction in the number of patients requiring third molar removal. Coding and data collection for third molars is not uniform, leading to potential misrepresentation of data. This perhaps raises the issue that an improved universal coding system is required for the NHS and that the NICE guidelines need review.

INTRODUCTION

Impacted third molars (wisdom teeth) are one of the most common developmental conditions that affect humans. It occurs due to a failure of proper eruption of the third molar tooth resulting in impaction of the tooth against adjacent teeth, alveolar bone, the surrounding mucosal soft tissue or combination thereof (Fig. 1). The impaction is defined in relation to the geometric angle of impaction such as mesio-angular, disto-angular, vertical and horizontal. If the tooth cannot fully erupt then its impaction will also be defined as partial, where some of the tooth has erupted into the oral cavity; or complete, where the tooth is buried and completely unerupted. The most common third molar tooth to be impacted is the mandibular third molar followed by the maxillary third molar. Third molar development tends to be bilateral although failure of the third molar to develop, either unilaterally or bilaterally, is not uncommon. Impacted third molars can cause a host of clinical problems that may necessitate the removal of the tooth to facilitate dental health.

Third molar surgery (TMS) is one of the most commonly performed surgical procedures undertaken in secondary care within the NHS. When combined with out-patient procedures undertaken in both secondary care and primary dental care it probably rates as the most common surgical procedure undertaken in the whole of the NHS. The presence of an impacted third molar is a developmental condition and is

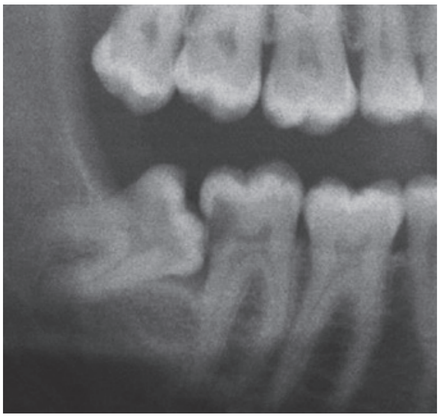

Fig. 1 Mesio-angular impacted third molar with caries *in-situ* and causing caries to the second molar. Lower right side

[1*-2]Consultant Oral Surgeon, King's College London Dental Institute
*Correspondence to: Dr Louis W. McArdle
Email: lwmcardle@msn.com

Refereed Paper
Accepted 14 May 2012
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©British Dental Journal 2012; 213: E8

recognised as such by the World Health Organisation within the definitions of the International Coding for Diseases (ICD-10).[1] It is accepted that the removal of a diseased or symptomatic third molar tooth will alleviate pain and symptoms and improve the oral health and function for patients.[2]

The National Institute for Health and Clinical Excellence (NICE) issued guidance on the management of third molars in 2000.[3] They surmised that up to 40% of third molars removed had no clinical indication for removal and that the practice of prophylactic removal should be discontinued within the NHS which, in turn, could generate an annual saving of £5 million for the NHS.

The impact of NICE's guidelines has not been properly evaluated and NICE's guidance remains the same. This paper aims to evaluate the impact of NICE guidance on the change in clinical practice based on the numbers of patients undergoing third molar surgery, the indications for surgery and the changes in patient demographics over the last 20 years, prior to and after the introduction of NICE guidelines.

NICE guidelines on the management of third molars followed the introduction of other notable clinical guidelines for third molar management. In 1979, the National Institute of Health in the USA issued their guidelines on the management of third molars partly as a result of comment by medical insurance companies that third molars where being removed unnecessarily without any evidence-based clinical indication.[4] In 1991, the American Association of Oral and Maxillofacial Surgeons introduced their guide and parameters of care document.[5] The first UK evidence-based guide to third molar management was issued by the Faculty of Dental Surgery of the Royal College of Surgeons of England in 1997 and most recently the guidance issued by NICE in 2000, complemented by the Scottish Intercollegiate Guidelines Network (SIGN) guidance also in 2000.[3,6,7]

NICE's main advice relates to the indications for removal of third molars and that the routine practice of prophylactic removal of pathology-free impacted third molars should be discontinued. Specifically, the clinical indications for the removal of impacted third molars should be limited to patients with evidence of disease (Fig. 2).

METHODS

To determine the trend in the number of patients in the UK having third molars removed over the last 20 years. Data was collated from the NHS Hospital Episodes Statistics (HES) database and the NHS Business Support Agency (NHSBSA).[8,9] In addition data was also collated from the Information Services Division (ISD) of the NHS in Scotland.

HES is an NHS database that records secondary care hospital-based activity in England and Wales. Included in the database are all patient diagnostic codes based on the World Health Organisation, WHO ICDN-10 codes and surgical activity codes based on the OPCS coding system. For England and Wales, primary dental care is evaluated by the NHS BSA who, in 2005, took over the role that the Dental Practice Board (DPB) had previously. The DPB recorded all dental procedure codes for each individual dentist with a General Dental Services (GDS) contract in the UK. This allowed treatment profiles of dentists to be collated and analysed. Within both of these databases, records exist for patients who have had third molars removed. Unfortunately, the NHSBSA stopped recording this data in 2006, as it was not part of their remit. From this data we can determine the relative level of third molar removal activity in the England and Wales. For Scotland the same primary care GDS and equivalent HES secondary care data is collated by the ISD of NHS Scotland. Figures for Scotland are reviewed separately to allow comparison post 2005 and the introduction of the new dental contract in England and Wales. In addition to these data, we have assessed HES data for the change of demographic profiles of patients and reviewed the clinical indication for the removal of third molars.

It is important to appreciate that the data recording by HES and the DPB/NHSBSA is different. Patients may have more than one third molar removed during a course of treatment and if one does not appreciate the nuances of data recording by these systems then the interpretation could be confusing. HES records the number of patients that have had one or more third molars removed whereas the DPB records the actual number of third molars removed. Consequently from HES data we do not know how many third molars were actually removed and conversely from the DPB data we do not know the actual number of patients who had third molars removed. Because of this, more third molars could be being removed in secondary care, as the data would allude to, and conversely the numbers of third molars being removed in primary care does not reflect the total number of patients and this has to be taken into consideration in collating and analysing the data.

i.	unrestorable caries
ii.	non-treatable pulpal and/or periapical pathology
iii.	cellulitis, abscess and osteomyelitis
iv.	internal/external resorption of the tooth or adjacent teeth
v.	fracture of tooth
vi.	disease of follicle including cyst/tumour
vii.	tooth/teeth impeding surgery or reconstructive jaw surgery, and when a tooth is involved in or within the field of tumour resection

Fig. 2 NICE's clinical indications for the removal of third molar teeth

RESULTS

HES finished consultant episodes

Data recorded by HES relates to the number of patients who have been admitted to hospital for either a day-case or in-patient procedures under either GA or IV sedation. In general, patients who have had third molars removed under local anaesthesia on an out-patient basis do not get included in HES data as this activity is recorded as an anonymous out-patient appointment and not as an out-patient surgical activity as with other surgical specialties. More recently, however, this type of activity has begun to be recorded but the true level of out-patient third molar removal is not known, and as such these out-patient figures may significantly underestimate the actual number of patients having third molars removed.

From the HES data,[8] approximately 50,000 people per annum in England and Wales had third molar teeth removed in the early period of the 1990s (Fig. 3). This number rose to 70,000 by the mid 1990s and averaged approximately 60,000 patients per year for the whole of that decade. In the first half of the 2000s patient numbers started to decline significantly

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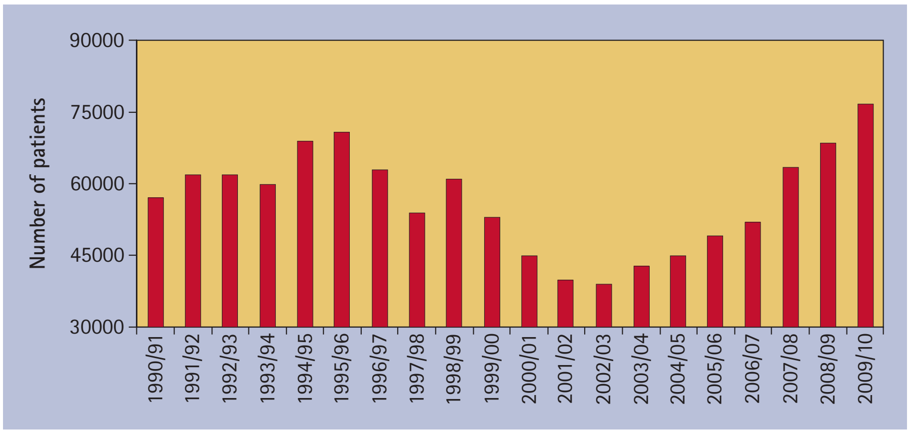

Fig. 3 Patients requiring third molar removal in secondary care: England and Wales

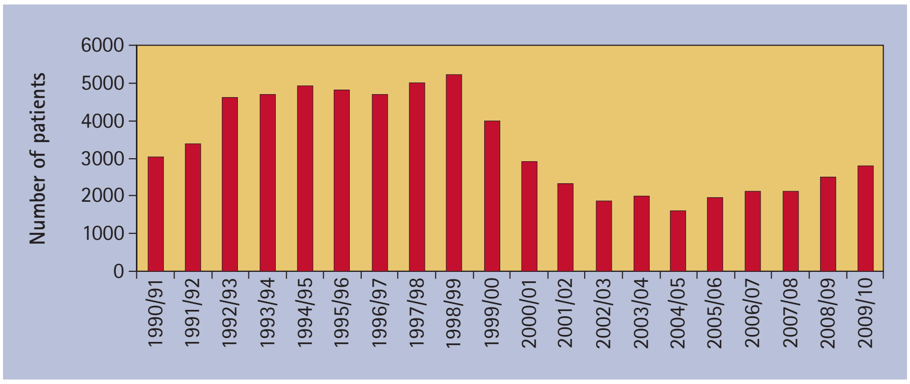

Fig. 4 Patients requiring third molar removal in secondary care: NHS Scotland

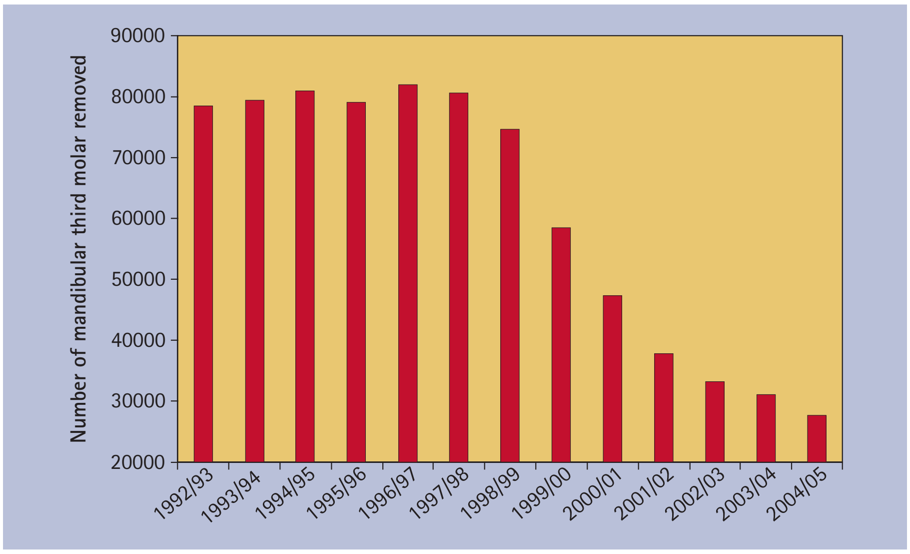

Fig. 5 Number of mandibular third molars removed in primary dental care: England and Wales

and by 2003 HES data suggests that less than 40,000 patients per annum were having third molar treatment undertaken in a hospital setting as either in-patient or day-case procedures: a reduction on the 1990s average of over 30%.[8]

From the mid 2000s onwards, the recording of a small amount of out-patient activity has been included in HES data along with in-patient and day-case data. Over the latter 5 years of the 2000s the number of patients having third molars removed had increased to almost 77,000 patients per annum in 2009/10 (65,000 in-patient/day-case; 12,000 out-patient). This equates to an approximate increase of 67% of in-patient and day-case activity recorded in the secondary care sector but a 97% increase in all recorded patient activity. By 2009/10 patients having third molars removed in a hospital setting was most notably at its highest level for 20 years.[8]

In Scotland, figures for in-patient/day-case activity follow a similar trend to England and Wales (Fig. 4). For most of the 1990s just under 5,000 cases of third molar removal were undertaken per annum. Subsequent to the introduction of the SIGN guidelines a similar trend in the number of cases per annum was noted, dropping to approximately 1,600 cases per annum by 2005: a reduction of approximately 70%. Post 2005, however, a steady year-by-year increase was noted and by 2009/10, the numbers of patients had increased to approximately 2,800 cases: an increase of 67% from the low of 2004/5.

NHSBSA/DPB 2204/2205 codes

The NHSBSA/DPB records items of treatment of each patient rather than treatment episodes for patients.[9] The Statement of Dental Remuneration (SDR) document provides the item of service codes used previously under the old General Dental Services Contract.[10] SDR Codes 2204 and 2205 are third molar specific and although third molars would have undoubtedly been removed under other codes such as 2101 and 2201, these codes are not tooth specific and cannot be used to identify third molar activity. In addition, SDR codes 2204/5 can identify both mandibular and maxillary teeth separately. This data set is limited to exclusively mandibular third molars, as the combined total of both maxillary and mandibular third molars removed may not accurately reflect the actual number of patients having third molar surgery. By restricting our data set to exclusively mandibular third molars we get a less distorted perception of the actual number of patients. In addition, mandibular third molars tend to cause greater clinical problems, are more surgically complex and have greater post-operative morbidity, making them the focus for most published research.

For the period of 1992–2005 in England and Wales GDS, the trend in third molar activity follows a comparatively similar pattern to secondary care (Fig. 5). For most of the 1990s approximately 80,000 mandibular third molars were being removed per annum. Subsequent to 2000, the numbers of mandibular third molars removed declined steadily by over 60% reaching a level of 28,000 per annum for 2004/5. Data for after this period is not available, as the NHSBSA no longer records it.

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In Scotland, data for third molar activity continues to be collated for general dental practice (Fig. 6). In the first half of the first decade of the new millennium, there was a 36% fall in mandibular third molars removed, mirroring the yearly trend of reduction in England and Wales. After 2004, however, mandibular third molar removal progressively increased and by the end of the decade was 130% greater than at its lowest level of 2004. This trend cannot be properly compared with the post-2005 new General Dental Services (nGDS) trend in England and Wales but it does complement the upward trend of secondary care third molar activity seen in both England and Wales, and in Scotland, which saw an increase of 67% over the same time period for day-case/in-patient procedures.

Age

HES data reports that the average age of patients requiring third molar removal within the NHS has increased over the last 20 years. In 1990, the average age of a patient having third molars removed as a day-case/in-patient procedure was 25 years. This mean age has steadily risen and now the mean age for patients having third molars removed as a day-case/in-patient is 32 (Fig. 7).[8]

Clinical indications for third molar removal in secondary care

HES data also records the main clinical diagnosis for third molar removal (Fig. 8).[8] The most common recorded OPCS-10 coding and indication for third molar removal relates to embedded and impacted teeth (K01.0/K01.1), paradoxically these are not a NICE indication for third molar removal. In 1995 embedded/impaction is recorded as the main diagnosis for approximately 70% of all third molars removed (Fig. 4). Over the next 15 years there was an increase in the proportion of caries or related peri-apical abscess (K02.9/K04.7) being recorded as the main diagnosis from less than 10% in 1995, rising to almost 30% by 2009. In the same period, periodontitis (K05.2/K05.3), as a recorded main diagnosis, stayed at a relatively constant level at approximately 15%. One notable anomaly from the coding system is that pericoronitis is coded as periodontal disease and not as a separately defined condition.[1]

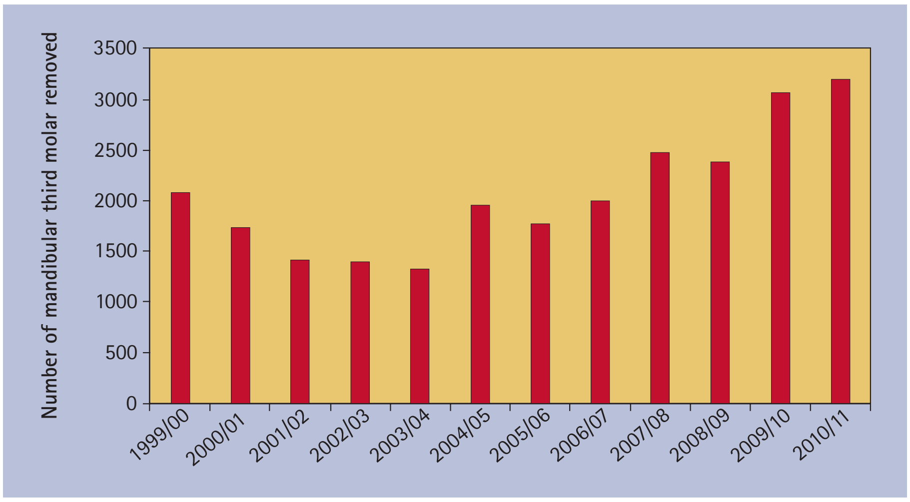

Fig. 6 Number of mandibular third molars removed in primary dental care: NHS Scotland

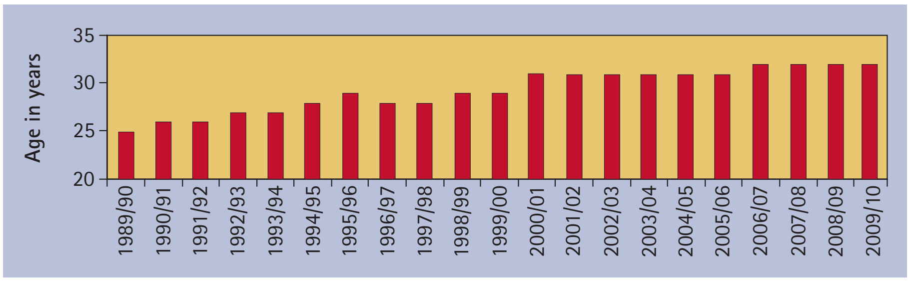

Fig. 7 Average age of patients requiring third molar removal in secondary care: England and Wales

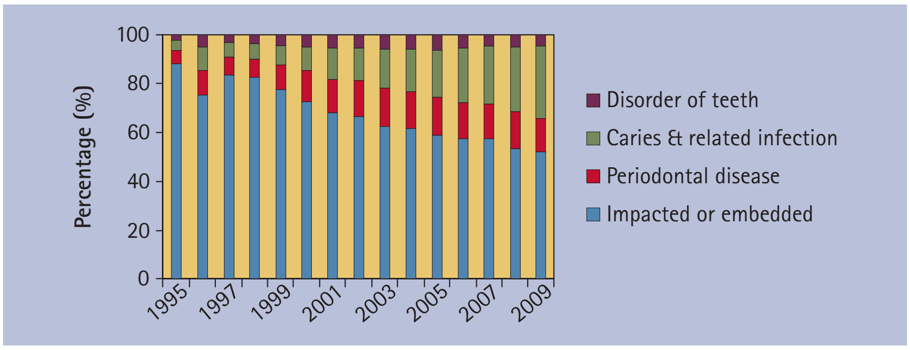

Fig. 8 Main clinical diagnosis for third molar removal in secondary care: NHS England and Wales

DISCUSSION

In 2004, a review of the impact that NICE guidance was having over a range of clinical interventions suggested that NICE had no discernable effect on the management of patients with third molar teeth.[11] Data used by this study covered the period from 1995-2001, which observed a downward trend in third molar removal during this time. It was suggested that the downward trend in third molar removal had already begun as a consequence of guidance issued by the Royal College of Surgeons of England in 1997 and by the University of York in 1998.[6,12] The sampling period of data was short and only included a single year after the introduction of NICE. Data prior to 1995, however, suggests that third molar removal was at a similar level for most of the 1990s with 1995 being the peak year within that decade. With the introduction of NICE's guidelines only occurring in 2000, it seems inappropriate to make this conclusion after only one year's worth of post-NICE data and a relatively short sample period.

It would appear that a decline in patients having third molars removed did start in the late 1990s with the introduction RCS(Eng) guidelines but our data suggests a significant reduction of third molar removal with the introduction of the NICE/SIGN guidelines in 2000.[11] It may be that

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the staggered introduction of the RCS(Eng) guidelines, the University of York's clinical effectiveness document and the NICE/SIGN guidance continued to reinforce the advice to the dental profession that third molars need not be removed.[3,6,7,12]

In general dental practice the numbers of third molars being removed reduced by over 50% by 2005. For secondary care, data showed a 40% reduction in patients having third molars removed from a peak of 70,000 in the late 1990s down to 40,000 in the mid 2000s. On NICE's premise that 40% of all third molars being removed had no clinical indication for removal, then this data suggests that third molar guidelines were having the desired effect of reducing the number of third molars being removed and therefore reducing healthcare expenditure in this area.

Although data post-2005 is not available for the GDS in England and Wales, the data from Scotland and HES would suggest that this dip in primary care third molar activity in England and Wales might also be only temporary. Within secondary care in England and Wales, the fall in third molar activity mirrors primary care with numbers steadily falling from the late 1990s until 2002/3. Following this, however, the numbers for third molar removal in secondary care began to rise steadily with an increase from 39,000 patients per year in 2002/3 to almost 77,000 patients by 2009/10 (65,000 in-patient/day-case; 12,000 out-patient): a total increase of 97% in 7 years. Furthermore, the data from NHS Scotland mirrors this increase in third molar activity by 67% in secondary care provision, and by 130% for general dental services for the latter half of the 2000s.

The reasons for this increase in third molar activity in the latter half of the 2000s and the specific increase in secondary care activity may be explained by two possible hypotheses:

- The possible influence of the new General Dental Services (nGDS) contract in England and Wales in 2005
- A link between the increasing age of patients and the increasing incidence of caries related to third molars.

The new General Dental Services

The new General Dental Services (nGDS) contract was introduced in England and Wales in March 2006, whereas the GDS contract in Scotland has remained relatively unchanged. Dental treatment was previously provided at a cost per treatment item. The new GDS contract is based on the provision of treatment within treatment bands. At present, the treatment band generates the fee rather than the service item, or the quantity of different service items. Consequently, this results in NHS dentists receiving the same fee for a course of treatment that may include just a single restorative procedure and the exact same fee for a course of treatment for multiple restorative procedures, endodontic procedures and extractions. In this example the fee for a band 2 course of treatment may be in the region of £60-£70 and realistically this limited fee for multiple items of treatment does not necessarily cover the actual cost of providing the treatment.

As the contract does not offer remuneration based on the time the dentist spends with the patient, nor for the number nor complexity of treatment items, it has been suggested that dentists are unwilling to undertake some of the more complex treatment items on the NHS and are subsequently referring patients to other providers for treatment.[13] The new GDS contract allows GDPs to refer patients for treatment that they themselves do not feel able to provide, whilst still claiming payment for the treatment. This may explain why referrals to hospital secondary care providers for oral surgery procedures, such as third molar extractions, has dramatically increased over the last five years. As such, oral surgery referrals to this teaching hospital in London have observed a 100% increase since 2004/5.[14] These observations may only be partly attributable to the increase in third molar removal in secondary care over the last five years, as the trend in secondary care third molar removal had already started to rise prior to the introduction of the new contract. From the trough of 2003 through to 2005, the year before the new contract was introduced in England and Wales, third molar activity was already on the increase. In Scotland, this upward trend in third molar removal post-2005 is mirrored in both primary and secondary care settings, suggesting that the upward trend in England and Wales may be multi-factorial.

Dental caries and age

In relation to third molars, caries can affect the third molar itself or more significantly occur in the distal cervical area of the second molar tooth due to the mesio-angular impaction of the third molar against it. Caries is a disease that is relatively slow to develop compared with pericoronitis and as a consequence caries develops later in patients by comparison.[15,16] From the HES data we have observed a significant increase in the number of patients requiring third molar removal. For the last ten years the recorded incidence of caries and its sequalae, as an indication for removal, has increased from less than 10% to almost 30% of all patients requiring third molar removal.[8] Over the last ten years the recorded incidence of patients having third molars removed due to dental decay has increased by over 200%.[8]

It may be that the rapid dip in the number of third molar extractions in the early 2000s was due to a rigid interpretation and application of third molar guidelines and as such third molars were actively not removed. This may be true in cases of single or mild forms of pericoronitis or solely the presence of a partially erupted and impacted third molar that may have been used as the indication for removal pre-2000.

Third molars are not erupting later in life to account for the increase in mean age from 26 to 32 during the last 20 years. Third molars are being retained for longer, either as a result of lack of disease affecting younger patients, or a palliative approach to the management of third molar disease. Patients may be more inclined to be treated with antibiotics for recurring episodes of pericoronitis and thus avoid, or more likely, delay the removal of the third molar.

The fact that patients are retaining third molars later into life makes them more vulnerable to one of the problematic consequences of the oral environment: dental caries. The likelihood of this will be evident especially if the teeth are impacted, partially erupted and difficult to clean. Older patients with good dental health are more prone to having third molar teeth removed because of caries related indications such as DCC in the second molar.[15-19] This data confirms that as patients have become older, dental caries has become an ever-increasing problem related to third molars. This group of patients may be contributing to the rebound increase in the number of third molars being removed.

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With the mean age of patients increasing from 26 to 32 years of age, we see an increase in the number of patients requiring third molar removal due to caries. Over the age of 30, patients are more likely to have third molar teeth removed due to the effects of caries than those who are younger.[15-18] Consequently, would it be reasonable to consider that any asymptomatic, partially erupted, impacted third molar, if retained, may ultimately cause patients clinical problems such as caries? If these problems are detrimental to the dental health of the patient then should we not consider defining the optimum time for removal – either at the time of disease presentation or even prior to the damage that the disease may cause – especially if the damage is related to the second molar in the form of distal cervical caries?

ICD-10 coding

There appears to be a lack of specificity in coding as it relates to studies such as this, which leads to problems in interpretation. Caries as a diagnosis is too non-specific for coding purposes. Caries associated with the third molar is an indication for third molar removal but distal cervical caries (DCC) on the second molar in the presence of a mesio-angular third molar is also an indication for third molar removal. Both of these clinical conditions appear to be on the rise in older age groups.[15-18] The coding system does not allow us to isolate the nature of the decay and as a consequence limits our ability to interpret accordingly. Nonetheless, caries related to third molars is on the increase and its consequences have to be managed.

Pericoronitis is a definable clinical problem that affects partially erupted teeth and accounts for the removal of up to 60% of all mandibular third molar teeth.[20-24] Pericoronitis is not, however, recognised by the WHO-ICDN coding system as a unique diagnosis and its classification as periodontal disease is erroneous.[1] This flaw creates serious problems in accurate data interpretation. If databases are recording ICD-10 codes of K05.2 or K05.3 do they mean periodontal disease or pericoronitis? Local periodontal disease affecting the second molar tooth, in addition to periodontal disease of the third molar itself, are distinct indications for third molar removal, but to classify both pericoronitis and periodontal disease together is inappropriate and makes data interpretation difficult.

Impaction and embedded teeth are not in isolation an indication for third molar removal but merely an observation of the ectopic position that the tooth develops into. A tooth's abnormal position is a developmental anomaly and along with other developmental anomalies is defined within the ICD-10 coding system.[1] This developmental anomaly ultimately accounts for the disease processes that affect impacted teeth, but recording the developmental anomaly rather than the disease that it predisposes, creates an imbalanced observation of the indications for third molar removal. In view of the actual HES incidence of impaction being comparable with the reported incidence of pericoronitis, it could be presumed that impaction is being recorded instead of pericoronitis.[2,8,20-24]

Accurate data collection in third molar studies and clinical coding systems is essential if data is to have any meaningful value. If the WHO ICD system is to be used for third molar data collection then it will require an overhaul to be fit for this purpose and to appropriately reflect the actual disease processes that afflict third molars.

CONCLUSION

With the introduction of clinical guidelines a decline in patients having third molars removed has occurred. This trend, however, has now been reversed and has steadily increased to pre-NICE levels. Any initial financial savings would have been short-term and with more patients attending secondary care for third molar procedures, costs are now greater than prior to the introduction of NICE. Patients are becoming older and more patients are experiencing caries as an indication for third molar removal even though the dental and oral health of the population continues to improve.[25,26] Indeed patients with mandibular third molars who succumb to DCC on their second molar teeth have on average better dental health than their peers.[16]

It has been appreciated for some time that as the dental health of the population has improved, the early loss of first molar teeth in children and adolescents does not occur as frequently as before.[27] Early loss of the first molar results in the forward drift and/or tipping of the second molar, creating space distally for the third molar to erupt unhindered and thus reduces the likelihood of impaction. Conversely, retention of the first molar restricts this space in the retro-molar area and no doubt contributes to the likelihood of impaction of the third molar tooth.[27] The increase in third molar surgery seen over the last 30-40 years may not be due to inappropriate over-prescribing or prophylactic third molar removal but may, in fact, be due to the paradoxical consequence of improved dental health. It is likely that the number of patients requiring third molar removal will always be substantial.

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Distal cervical caries in the mandibular second molar: an indication for the prophylactic removal of third molar teeth? Update

Louis W. McArdle[a,*], Fraser McDonald[b], Judith Jones[c]

[a] Department of Oral Surgery, KCL Dental Institute, Guy's & St Thomas's NHS Foundation Trust, Great Maze Pond, London SE1 9RT, United Kingdom
[b] Department of Orthodontics, KCL Dental Institute, Guy's & St Thomas's NHS Foundation Trust, Great Maze Pond, London SE1 9RT, United Kingdom
[c] Department of Oral Surgery, QMUL Dental Institute, The Royal London Hospital NHS Foundation Trust, Whitechapel, London E1 1BB, United Kingdom

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Abstract

In 2005 we reported the clinical findings of 100 patients who had mandibular third molars removed because of distal cervical caries in the mandibular second molar. The aim of this follow-up study was to find out whether the findings in a new group of patients corroborate those of our previous study. We report on the clinical features of 239 patients (mean (SD) age 32.1 (7.85) years, range 20–65) who had 288 mandibular third molars removed because of distal cervical caries in the second molar. Patients had better dental health than average, and 67% had a DMF (decayed, missing, or filled) score of 5 or less. In 89% of third molars the mesial angulation was between 40° and 80°. Distal cervical caries in second molars is a late complication of third molar retention. The prophylactic removal of a partially erupted mesioangular third molar will prevent distal cervical caries forming in the second molar tooth.

Keywords: Third molar; Indications; Distal cervical caries

Introduction

Current UK clinical guidelines for the management of third molars advise against the prophylactic removal of healthy impacted teeth,[1–3] and suggest that there is no reliable evidence to support it. Consequently, current practice is to remove teeth only if they cause disease.[4]

Partially erupted, mesioangular impacted mandibular third molars that are in contact with the second molar around the amelocemental junction put the second molar at risk of developing distal cervical caries (Fig. 1),[5–8] which is a carious lesion that forms on the distal cervical root surface of the second molar. Mesioangular impaction of the third molar on to the second molar creates a deficient gingival collar and exposes the distal root surface of the second molar to the oral environment. The area is difficult to keep clean so dental plaque forms and persists, and results in distal cervical caries in the second molar. The third molar must be removed to enable restoration of the second molar, but in certain cases this might not be possible, and the second molar may also need to be extracted.

In 2005 we reported on 100 patients who had mesioangular impacted third molars removed because of the presence of distal cervical caries in the second molar.[8] They tended to be 5 years older than the average for patients having third molars removed and their dental health was also better than average.[8] We suggested that these patients presented with distal cervical caries because earlier in life they had not had any serious third molar disease such as pericoronitis, which would have indicated removal of the tooth.[8] Consequently, retention of these teeth promotes the formation of distal cervical caries in the second molar.

* Corresponding author. Tel.: +44 020 7188 3435; fax: +44 02071884360.
E-mail address: louis.mcardle@kcl.ac.uk (L.W. McArdle).

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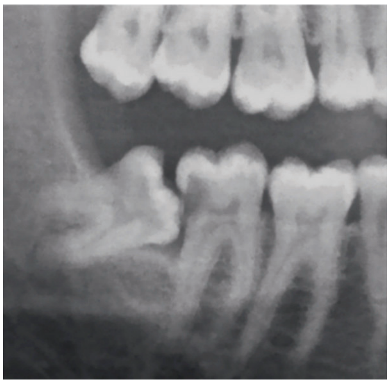

Fig. 1. Radiograph of distal cervical caries in the mandibular second molar with associated impacted mesioangular third molar.

The aim of this follow-up study was to assess a further group of patients with distal cervical caries in their mandibular second molars to find out if the findings corroborated those of our 2005 study.

Methods

We evaluated 239 patients who had mandibular third molars removed because of the presence of distal cervical caries in the second molar. Data were prospectively collected over a 24-month period.

The variables that we recorded were sex, age, angulation and eruption status of the third molar, DMF (decayed, missing, or filled) score, and the proximity of the third molar to the amelocemental junction of the second molar.

As in our previous study, the DMF score was used as a measure of dental health. In calculating the score we compensated for, and excluded, the second molar if distal cervical caries was the only lesion associated with the tooth. The mesial angulation of the third molar was calculated by measuring the angle of intersection between the mandibular occlusal plane and the occlusal plane of the third molar. This angle equates to the mesial inclination of the third molar relative to the second molar.[8]

Results

The study included 239 patients (142 men and 97 women). In 190 patients, a single second molar was affected, and both were affected in 49 (bilateral disease). In total, 288 mandibular third molars were extracted, 144 from each side.

The mean (SD) age of the patients was 32.1 (7.85) years (range 20–65) (Fig. 2). A total of 161 patients (67%) had a DMF score of 5 or less; 56 (23%) had a score of between 6 and 10, and 22 (9%) had a score of 11 or more. Of note, 50 patients (21%) had a compensated DMF score of zero as the only lesion was the distal cervical caries associated with the second molar tooth.

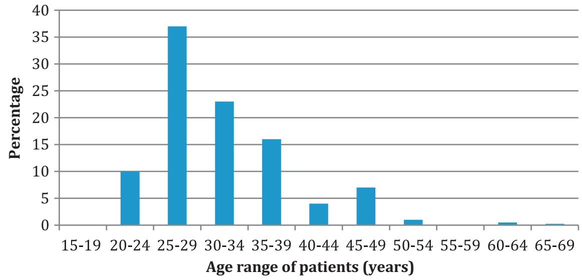

Fig. 2. Age range of patients (years) compared with percentage number of patients. Mean (SD) age 32.1 (7.85) years (range 20–65).

All 288 teeth were partially erupted. Radiographic examination showed that all were in contact with, or close to, the amelocemental junction of the second molar, and all were mesioangularly impacted against the second molar. Mesial angulations of the third molars were grouped accordingly: 255 (89%) had an angulation of between 40° and 80°; in 28 (10%) it was less than 40°, and in 5 (1%) it was more than 80°.

Discussion

To our knowledge, distal cervical caries in the second molar has not been reported without an associated mesioangular third molar, and we have not observed it. Although caries can form on the distal aspect of any tooth, distal cervical caries is unique as it is seen at the amelocemental junction and is, in effect, a variant of root surface caries. We think that it would not develop without an associated impacted third molar.

Concern has been raised that in some studies, radiographic cervical burnout may have been misdiagnosed as distal cervical caries resulting in a higher reported incidence.[9] In this study, as in our previous study, patients whose radiographic images suggested cervical burnout were excluded from the study (Fig. 3).

A factor that is associated with the risk of distal cervical caries developing in the second molar is the angulation of the third molar. This type of second molar caries is seen

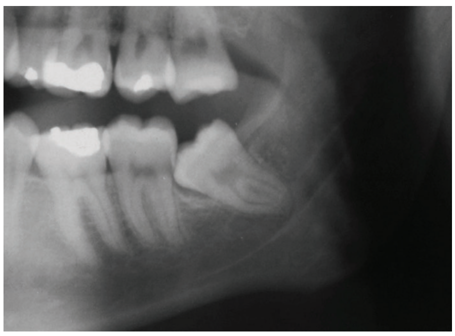

Fig. 3. Radiograph of radiographic distal cervical burnout potentially misinterpreted as distal cervical caries.

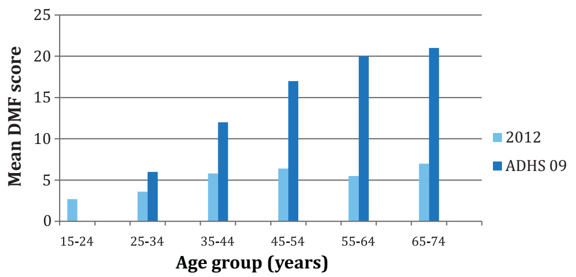

Fig. 4. Mean DMF (decayed, missing or filled) score of patients having third molars removed because of distal cervical caries (2012) (light blue) compared with mean DMF score calculated from the Adult Dental Health Survey 2009 (dark blue).[15]

primarily in association with mesioangular impacted third molars and, as in other studies, we found that a mesial angulation of between 40° and 80° was common.[8–14] Of the 288 third molars extracted, 255 (89%) were within this range. Mesial angulations outwith this range and in some cases of horizontal impaction have been associated with distal cervical caries in second molars, but it has not been seen in vertical or disto-angular impactions.

Based on the 2009 Adult Dental Health Survey (ADHS), the mean DMF score for patients with distal cervical caries was less than half the mean score for similar age groups in the general population (Fig. 4).[15] This also corresponds to our findings in 2005 which were based on the 1998 ADHS.[8,16] It supports our suggestion that patients with better dental health are more likely to retain a partially erupted third molar later into life, and when this is mesioangular, are at risk of distal cervical caries developing in the second molar.[8] It also contradicts the notion that susceptibility to distal cervical caries in second molars is solely associated with an increased susceptibility to dental caries.[5–7]

It is logical to assume that people with low DMF scores have a good standard of oral hygiene and this includes the coronal aspect of partially erupted third molar teeth. Good oral hygiene minimises the likelihood of pericoronitis and results in the long-term retention of such teeth, but in the case of a mesioangular third molar and a second molar with a distal cervical root exposed to the oral cavity, distal cervical caries is a potential outcome. It seems to develop in older patients and this may be reflected in the protracted time it takes for dental caries to form compared with the time it takes for pericoronitis to develop after a third molar has erupted.[8,17]

The mean age of patients in this study was 32.1 years (range 20–65), which is comparable with the mean age (32 years) for all patients who have third molars removed in the UK.[18,19] In our previous study patients with distal cervical caries tended to be 5 years older than average whereas this study suggests that they are similar in age.[19] This may be because in the UK, the introduction of third molar guidelines by the National Institute for Health and Care Excellence (NICE) and others has resulted in a shift

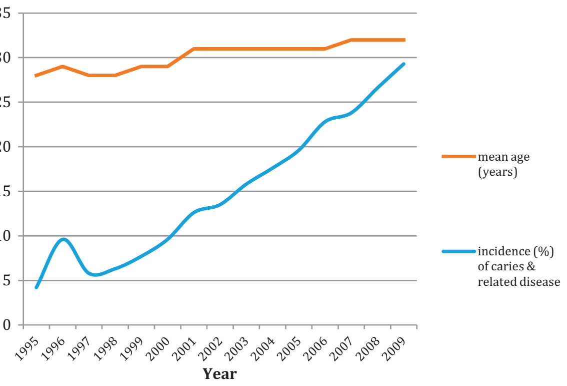

Fig. 5. Increasing percentage incidence of caries and related disease (blue line) as main indication for removal of third molars, and increase in mean age of patients (orange line) having third molars removed.[18,19]

away from the prophylactic removal of third molars, primarily in younger patients, to removal based on definitive clinical indications.[1–4,19] The consequence of this has been an increase in the mean age of patients from 28 to 32 years.[18,19] The incidence of third molars being removed because of caries and related sequelae such as periapical infection has also increased from 4% to about 30% (Fig. 5).[18,19] The mean age in our group suggests a relation with an increased mean age and a higher incidence of third molar caries in general, as is the case with an increasing incidence of distal cervical caries in older patients.[17,19]

It is not possible to isolate data from NHS agencies on caries that solely affect the third molar or on distal cervical caries of the second molar that is attributed to the third molar, but the general trend of an increase in caries related to third molars is noteworthy.[18,19] Distal cervical caries in second molars in association with impacted third molars is becoming more widely reported, and is not isolated to any specific racial group.[10–14] Recent studies have reported an incidence of up to 20% in patients having third molars assessed, and some report an incidence of about 40% in mesioangular impacted third molars.[10,11]

Older studies report a mean age of around 25 years for patients having third molars removed, and report pericoronitis as the most common indication.[20–24] As these studies were published when the prophylactic removal of third molars in younger patients was common, their mean age was lower.[20–24] The incidence of third molars being removed because of caries in younger patients is relatively low, and historically the reported incidence of distal cervical caries in second molars in these patients has also been relatively low (2–5%).[8,17,19,20]

As distal cervical caries is responsible for a rising percentage of third molars being removed we think that there is a high risk of it developing in a second molar.[10–14,17] However, pericoronitis is still the most common indication for the removal of third molar teeth, and it is diagnosed more often in younger patients.[5,7,17,20,23,24] In these patients the extraction of mandibular mesioangular third molars removes the main contributing factor for distal cervical caries in the second molar. If pericoronitis was less common in younger patients then more third molar teeth would be retained later into life. As a consequence, we suggest that the incidence of distal cervical caries in the second molar will rise accordingly, as is the case with that of general caries that are related to third molars in older patients.[17–19]

We need to consider whether all partially erupted mesioangular third molars would eventually cause distal cervical caries in the second molar. A study of this latent potential would require the enforced retention of a mesioangular third molar to observe its effect on the adjacent tooth, but this would be unethical and unavoidably protracted over many years. The introduction of clinical guidelines such as NICE has resulted in an older patient population whose third molars are retained until specific problems indicate their removal. In some respects the patient whose third molar is retained later into life is acting as their own control to the long term consequences of retention as is demonstrated by the increasing incidence of third molar caries (4-30%) correlating with the increasing mean age of patients (Fig. 5).

The potential risk of distal cervical caries forming in second molar teeth that are associated with mesioangular third molars presents a clinical dilemma: should the third molar be left until disease develops, or should it be removed, and if so, when? Clinical risk should influence the decision and the relative risk – for example, of nerve damage, is an important consideration. Early removal of a third molar with a high risk of injury to the inferior dental nerve may not be prudent and in such a case alternative options such as coronectomy could be considered.

Conclusion

We do not think that all third molars should be removed prophylactically, but early, prophylactic removal of a partially erupted mesioangular mandibular third molar will prevent distal cervical caries forming in the adjacent tooth. Mesioangular third molars will not always cause distal cervical caries to form as many will be removed because of pericoronitis and other diseases before it ensues, but we do suggest that every partially erupted mesioangular third molar has this potential. Only with further research and debate will we know whether or not targeted prophylactic removal of such teeth is acceptable. The cost–benefit and cost–effectiveness of this are complex issues and are out of the sphere of this paper, but prophylactic removal will be explored in further ongoing research.

The results of our 2 studies and others confirm that distal cervical caries in the second molar is associated with the retention of a partially erupted mesioangular third molar tooth into later life.[8,10–14] As this study corroborates our previous findings we suggest that the conservative management of disease-free, partially erupted, mesioangular mandibular third molars may be detrimental to dental health.

Conflict of interest

None.

Ethics statement

Not required.

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The mesially impacted mandibular third molar: The incidence and consequences of distal cervical caries in the mandibular second molar

Louis W. McArdle [a,*], *Nishma Patel* [a], *Judith Jones* [b], *Fraser McDonald* [c]

[a] *Department of Oral Surgery, KCL Dental Institute, GSTT NHS Foundation Trust, Great Maze Pond, London SE1 9RT, UK*
[b] *Department of Oral Surgery, Institute of Dentistry, Bart's & The London School of Medicine and Dentistry, Queen Mary University of London, Turner Street, London E1 2AD, UK*
[c] *Department of Orthodontics, KCL Dental Institute, GSTT NHS Foundation Trust, Great Maze Pond, London SE1 9RT, UK*

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ABSTRACT

Aims: Distal Cervical Caries (DCC) of the mandibular second molar (Md2M) is primarily related to retained mesially impacted third molars (Md3M). Treatment of this condition indicates the removal of the Md3M and the restoration of the Md2M and, on occasions, the loss of the Md2M. The aim of this study was to determine the incidence, treatment outcomes for patients, and calculate costs related to Md2M DCC.

Methods: A review of 121 patients who had Md3M removed due to Md2M DCC was undertaken to determine the treatment outcomes for patients. The number of patients affected by DCC of Md2M was calculated from the incidence of DCC (15%) in a cohort of patients requiring Md3M removal (1100) and the annual number of patients undergoing third molar surgery in England. Direct costs were calculated using NHS and independent treatment tariffs and indirect costs from Office of National Statistics (ONS).

Results: It is estimated that 152,000 patients in England undergo third molar removal on an annual basis. Approximately 27,000 Md3M are removed annually due to DCC of the Md2M; costing £27 m to treat with additional costs of £28 m if dental implant replacement of the Md2M is included. Total cost for treating Md2M DCC: £55 m/annum.

Conclusions: Treating Md2M DCC and its consequences is expensive for healthcare funders such as the NHS and for patients. Md2M DCC is avoidable if patients who are at risk have prophylactic Md3M removal. This would offer potential and substantial savings in the financial cost of treating an otherwise avoidable disease.

* *Corresponding author*. Tel.: +44 020 7188 4345; fax: +44 020 7188 4360.
E-mail address: louis.mcardle@kcl.ac.uk (L.W. McArdle).

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Introduction

The presence of partially erupted, mesio-angular, mandibular third molar teeth (Md3M) are a causal factor in the development of Distal Cervical Caries (DCC) on adjacent mandibular second molar teeth (Md2M).[1–7] DCC is defined as a carious lesion, which occurs at the exposed disto-cervical amelo-cemental junction of a tooth and is seen most frequently related the Md2M.[1,7] As a consequence of DCC formation, treatment of the second molar, either in the form of restoration of the second molar or removal of the second molar is indicated. Moreover, the diagnosis of second molar DCC will require the removal of the Md3M, not only to facilitate the restoration of the second molar but also to eliminate the risk of recurrence of DCC in the second molar.

Although the specific treatment of the second molar will be determined by various clinical and patient factors, the definitive treatment outcomes for patients with third molar related DCC of the second molar has not been quantified. This paper evaluates the treatment outcomes for second molar teeth affected by DCC in a cohort of patients who had their Md3M removed as a consequence of DCC and estimates the relative costs of managing this disease.

Method

Data from two previous published studies of patients with DCC in 2006 and 2014 were combined.[1,7] This data identified a total of 339 patients who had their Md3M removed due to DCC of the Md2M. Of these 339 patients, 121 patients had contemporary contact details. Advice was sought regarding the need for ethical approval but was deemed not be required. These patients were contacted and asked to confirm what the treatment outcome was for their Md2M tooth, subsequent to the removal of their third molar tooth: 84 patients responded.

Results

Of the 84 patients, 44 were female and 40 were male. 26 patients (30%) confirmed that their Md2M had either been extracted at the time of third molar removal or subsequent to third molar removal; 26 patients (30%) confirmed that they had had the second molar tooth restored and that it was still present. A further 10 patients (12%) confirmed that they had endodontic treatment of the second molar prior to restoration of the tooth. 22 patients (27%) could not recall what treatment they had for their second molar and could not confirm if the second molar tooth was present or not (Fig. 1).

Of the 84 patients, 38 were from the 2006 cohort and 46 from the 2014 cohort. Of the 2006 cohort; 24% of second molar teeth had been extracted, 45% were restored and 31% could not recall what treatment they had. Of the 2014 cohort: 35% had been extracted, 41% were restored and 24% could not recall what treatment they had.

Of the 62 patients who could recall the treatment outcomes for their second molar tooth, 26 patients (42%) had their second molar removed, 26 patients (42%) had their second molar restored and 10 patients (16%) had their second molar endodontically treated in addition to restoration (Fig. 2).

Discussion

DCC in the second molar is most commonly associated with Md3M teeth but it is also seen with maxillary third molars.[1–7] The majority of third molars associated with DCC on the second molar are mesio-angularly impacted, with a smaller incidence observed with horizontal impactions: DCC has not been observed in association with vertical, disto-angular, or ectopic impactions.[1,7]

The presence of the partially erupted mesio-angular third molar impacting against the second molar creates a deficient gingival collar around the second molar tooth which results in exposure of the distal cervical root surface of the second molar to the oral environment.[1,7] The inaccessibility of this area for adequate oral hygiene results in cariogenic plaque formation and consequent dental caries in this area. The partially erupted third molar is causal to the formation of DCC in the second molar as it is not observed in the absence of an adjacent third molar.[1–7]

As already stated, treatment outcomes for patients with DCC include removal of the third molar to facilitate restoration of the second molar tooth. Conservative treatment of the second molar tooth may involve uncomplicated restoration of the tooth but in some cases the tooth will also require endodontic treatment and more complex and expensive restoration. In other cases it may not be possible to restore the second molar and removal may be indicated either concurrent with the removal of the third molar, later if restoration of the second molar becomes unfeasible or; ultimately it may, in its own right, fail at a later stage. In patients in which it is not feasible to restore the second molar tooth and this tooth is indicated for removal, the third molar may, in some cases, be retained if it is disease free, as removal of the third molar may be clinically meaningless. In the majority of cases of patients with DCC in the Md2M the immediate and long-term prognosis for this tooth is poor and the likelihood of the tooth lasting indefinitely would be guarded.

Restoration of the second molar tooth whilst overlooking the need for removal of the third molar tooth is not clinically pragmatic. This makes restoration of the second molar difficult and ultimately the third molar persists in compromising the second molar either from the risk of secondary DCC or periodontal problems (Figs. 3–5). In cases where potential third molar removal will have a significant risk of IDN injury consideration may be given to undertaking a coronectomy procedure on the third molar to eliminate the casual influence and the potential effect of the third molar.[7]

In estimating the cost of DCC, a number of factors need to be taken into account. The number of patients with DCC and the proportion of different treatment outcomes related to these patients have to be calculated. In addition, the direct monetary cost of each of treatment modality and the indirect costs of treatment need to be quantified. The cost of second molar DCC may be difficult to calculate as, although the loss or restoration of a tooth has a financial cost, the ongoing long-term costs of maintenance and possible loss will change with individual

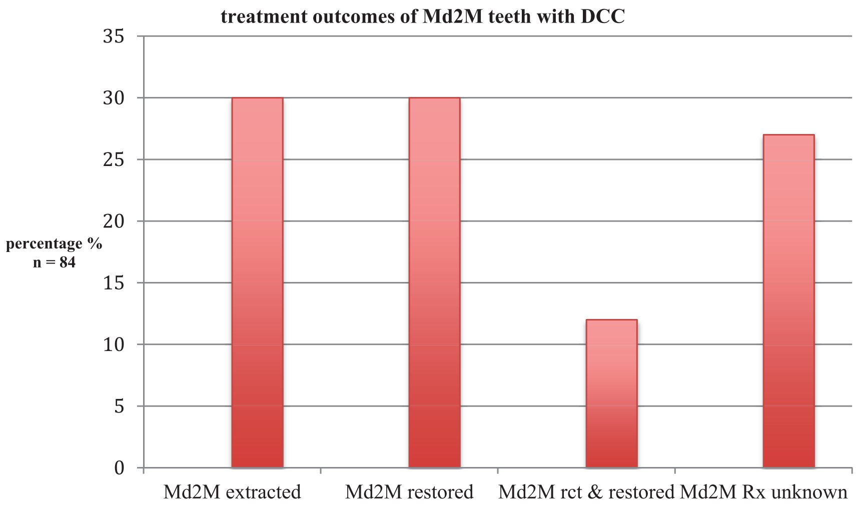

Figure 1 – Reported outcomes for patients with DCC in Md2M.

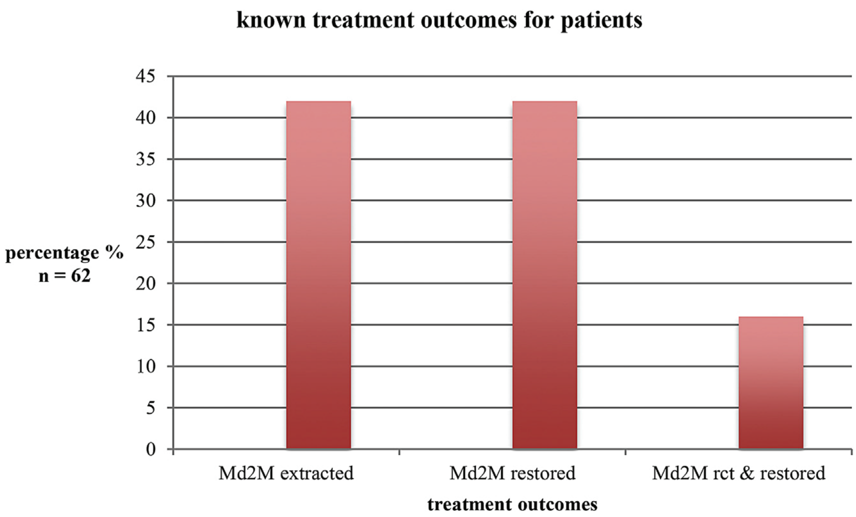

Figure 2 – Known reported outcomes for patients with Md2M DCC.

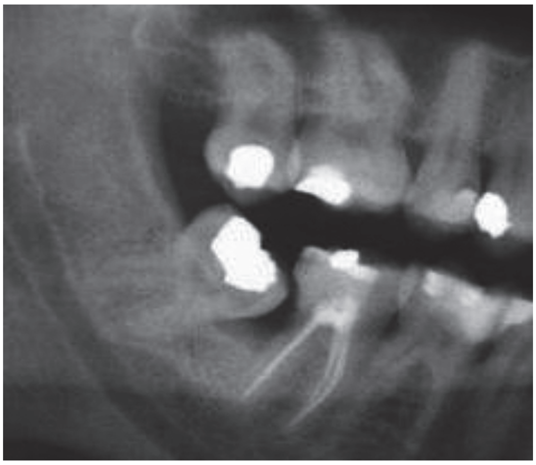

Figure 3 – Md2M (47) RCT'd and restored with deficient restoration distally. Retained mesially impacted Md3M (48) restored due to caries.

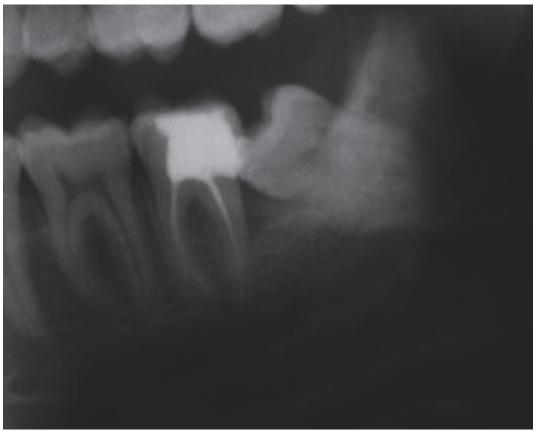

Figure 4 – Md2M (37) RCT'd and restored with compromised periodontium and loss of clinical attachment distally. Mesially impacted Md3M (38) retained.

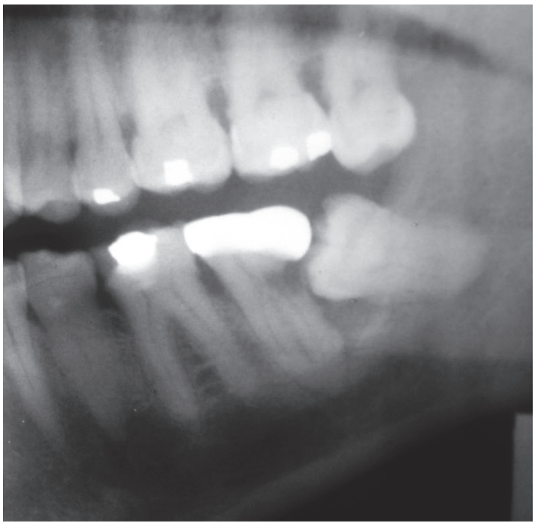

Figure 5 – Mesially impacted Md3M (37) with associated DCC on Md2M that has previously been crowned.

circumstances. In addition, costs tend to be qualified, not only by these direct costs of the intervention, but also by the indirect costs for the patient such as loss of patients' earnings due to time off work, loss of productivity due to absence from work and intangible costs such as pain, incapacity and compromised occlusal function if the second molar is lost.

How many patients may be affected by DCC?

It has been reported that Md2M DCC may contribute to between 5% and 40% of all Md3M removed.[1,2,7] These figures may be underestimated and may be increasing as a consequence of the changing practice in the management of third molar teeth.[8–10] The incidence of caries as an indication for third molar removal has risen from less than 10% in 2000 to 30% in 2010.[8,9] DCC is predominately seen in patients in their early 30s and it has been reported that the mean age of patients having third molar removal has increased from 28 to 32 during this time period also.[1,7–9] In considering both of these factors it may be reasonable to presume that the incidence of DCC will also have risen during this period. Unfortunately NHS datasets do not record DCC as a specific diagnosis for third molar caries, however audited data based sample of 1100 patients has demonstrated that second molar DCC accounts for approximately 15% of all patients requiring Md3M removal.[11] Furthermore DCC is seen predominately related to mesio-angularly impacted third molar teeth and consequently the incidence of DCC solely related to mesio-angular third molar impactions will be substantially more.[1–7]

Data collection related to third molar removal is poor in the UK as there is no accurate record of patients undergoing third molar removal on an annual basis.[8,9] Primary care data for third molar removal has not been recorded since 2004/5 and in hospital admitted in-patient and day-case activity is recorded but data for out-patient third molar removal under local anaesthesia is poorly recorded which accounts for a significant proportion of secondary care third molar activity.

Nonetheless, using data from online Hospital Episodes Statistics (HES) and internal hospital dataset statistics we can estimate the volume of third molar removal undertaken on an annual basis. From HES online we can calculate that in 2013/14 there were approximately 67 k patients requiring third molar removal as an in-patient or day-case hospital admission in England and 16 k on an out-patient basis.[12] These treatment episodes only represents a fraction of all third molar activity as historically third molar removal under local anaesthesia within the hospital secondary care setting is poorly recorded as an actual third molar treatment episode. Guys and St Thomas's NHS Foundation Trust (GSTT) is a large tertiary teaching hospital in central London. Its Oral Surgery Department undertakes in excess of 2300 patient treatment episodes for third molar removal on an annual basis. Data sets relating to these patients demonstrate that approximately 1500 patients are admitted for third molar removal under day-case general anaesthesia or sedation and 800 patients on an outpatient, local anaesthetic basis.[13] If we consider the oral surgery department of GSTT to be typical of secondary care oral surgery provision in England, and we extrapolate the ratio of admitted patients versus out-patients to the 67 k patients in England having third molar removal on an admitted basis, then we can estimate the total number of patients in England having third molar removal in a secondary care setting. Based on this calculation we can estimate that nationally, in the region of 38 k patients have third molar removal on an outpatient basis giving a estimate of 105 k patients for secondary care activity.

Unfortunately, the NHS does not now record the number of patients having third molar removal undertaken in NHS primary care. The last year for which the NHS Business Services Authority (NHSBSA) recorded data was in 2004/5 and in this year, 28 k Md3M were removed in NHS primary care.[14] (NHSBSA data recorded the actual number of third molar teeth removed as opposed to HES which records the number of patients having at least one third molar removed[9,14]). It is not, therefore, possible to calculate the true volume of primary care third molar activity, as there are no contemporary datasets to make an accurate calculation. However, from 2004/5 there has been rebound increase in day-case hospital based activity of 67%.[9] If this increase is mirrored in primary care then it can be estimated that 47 k Md3M may be being removed in primary care on an annual basis. Based on these actual and estimated numbers the minimum number of patients having third molar removal in England may, therefore, be in the region of 152 k, however the actual number, in reality, may well be much higher.

Based on a potential 15% incidence of second molar DCC and the potential 152 k patients per annum it can be estimated that potentially 22.8 k patients per annum in England may now be being diagnosed with DCC in a second molar tooth due to an impacted third molar. In addition, it has been reported that approximately 20% of patients with DCC of their second molar as an indication for the removal of the third molar have bilateral DCC.[1,7]

This results in a potential of 27 k Md2M teeth that may be affected by DCC as a result of an impacted Md3M tooth. Based on the outcome data of treatment this may result in potentially 11.4 k (42%) Md2M being extracted and requiring possible replacement; 11.4 k (42%) that will require restoration, and 4.2 k (16%) requiring root canal treatment and restoration.

Direct financial costs

Due to the idiosyncratic system of funding of NHS treatment in England, the true financial cost of treating this disease is difficult to quantify as primary care NHS treatment costs are based on courses of treatment rather than the actual service provision of a specific item of treatment. However, based on the funding provisions in England the actual cost of either a simple restoration of the second molar or its removal in primary care may be in the range of £75 per case but for more complex treatment including RCT with a crown/inlay restoration this may be in the region £300 per case (based on rate of £25/UDA[15]). The cost in terms of patients who choose private dental treatment and specialist NHS provision will be substantially more. Consequently, based on NHS primary service funding, the primary care cost of treating DCC conservatively may be between £1.7 m–£2.1 m per annum in England. (calculation based on lower and upper estimations of DCC patients {22.5 k × £75 = £1.7 m} & {27.5 k × £75 = £2.1 m})

In hospital based secondary care the total cost of third molar removal will be in the range of £1000 per case for day-case procedures and £400 per out-patient procedure as based on the 2014 NHS treatment tariffs.[16] For patients with DCC the cost amounts to approximately £10 m for third molar management under day-case {(67 k × 15%) × £1000 = £10 m} and £2.3 m for third molar management on an out-patient basis {(38 k × 15%) × £400 = £2.3 m}: A total of £12.3 m per annum.

Management of impacted third molars in primary care is now being provided more regularly by primary care based oral surgery specialist services. In NHS primary care, oral surgery specialist care costs are in the region of £150–£250 per case. Unfortunately the NHS does not calculate the amount or proportion of work provided by this group, however if the primary care estimate of 47 k third molars is accurate then the volume of primary care third molars removals due to DCC, may be of the order of 7 k cases (15%). This would result in an estimated cost of primary care third molar removal between £1–£1.75 m per annum.

Although the loss of the second molar tooth may not significantly influence masticatory function or aesthetics, potential over eruption of maxillary second molars and patient choice to maintain an optimal functional dentition may indicate replacement of the Md2M tooth with an implant retained crown. Not all patients may be suitable for dental implant treatment but patients with DCC do tend to have better dental health than average.[1,7] Patients may also be less inclined to undergo implant treatment due to the requirement of further surgery; of potential inferior dental nerve morbidity and the general inconvenience of such a treatment option. It is difficult, therefore, to speculate how many patients would wish to replace a second molar tooth, but with the cost of this treatment being, on average, £2.5 k per implant-retained crown, this could total £28 m per annum if all patients (11.4 k/annum) who are estimated to have lost their second molar elected to have this treatment.

Indirect financial costs

Indirect costs are made up of loss of patient's earnings and loss of access for other patients, however these indirect costs of third molar removal can be more difficult to quantify.

Costs such as loss of patient's employment productivity and potential loss of earnings for patients having to attending for both third molar removal and for remedial dental treatment may add another notional £7 m/annum loss of earnings for time of work for third molar surgery and recovery plus £1.5 m/annum loss of earnings for the time spent on remedial treatment of the second molar. The former is calculated from the number of patients requiring third molar removal due to DCC (22.8 k patients/annum), the average recovery period for patients having third molars removed (3 days) and the resultant loss of earnings based on the UK average earnings value (£27.2 k/annum). The latter is similarly calculated from the potential number of patients experiencing DCC (22.8 k patients/annum with 27.5 k second molars/annum); an estimated average of 3 h of patient's time to attend the dentist for remedial treatment (including traveling time); and the loss of earnings based on UK average earnings value (£27.2 k/annum).[17–19] The financial cost to the economy is more difficult to quantify, however as these patients will generally be adults in their 30's the cost to the economy will be sizeable.

For the dentist themselves, remedial treatment may require an additional 27.5 k work-hours/annum to provide treatment for 27.5 k DCC patients that should be spent on treating other patients: in effect remedial treatment for DCC reduces access for other patients that will still have to be treated. (calculation based on a notional 30 min clinical time for simple restorations/second molar removal and 90 min clinical time for more complex treatments per patient). This may add a further notional £2.1 m/annum in indirect cost (based on time, average UDA rate of £25 and 27.5 k patient episodes/annum). This should not be considered as double accounting, as dentists undertaking treatment will still be have to provide treatment for other patients.

Overall the potential costs of treating second molar DCC are substantial and could potentially eclipse £55 m per annum (Fig. 6).

Supplementary considerations

NICE guidance has resulted in a change of practice towards managing *teeth* rather than managing *patients*.[8,20] Patients often have only a single problematic third molar removed in isolation whilst other impacted, but as yet asymptomatic, third molars are disregarded. It would seem prudent; therefore, to consider the long-term potential of disease by leaving these asymptomatic impacted third molars rather than ignoring it. As DCC is a late disease many patients with it may be subjected to multiple treatment episodes for individual third molar management over a long-term period rather than a single treatment episode for all third molars.[1,7,8] This in itself increases potential costs, as tariffs for third molar removal will be based on treatment episodes, irrespective of how many third molars are removed. With patients having a

Figure 6 – Cost Calculator of DCC in Md2M.

potential four third molars this could theoretically translate into four treatment episodes rather than a single, collective treatment episode for patients with third molars. Patients who have multiple treatment episodes will invariably cost the NHS and other funders more to treat over a lifetime than a single treatment episode. A holistic approach, whilst considering the potential for further problems of third molars may, in fact, be less detrimental to the patient and save money in the long-term.[8]

All mesio-angularly impacted third molar teeth pose a risk of DCC to the second molar tooth.[1,7,8] Not all risk is realized as most third molars are removed prior to the formation of DCC. It is those teeth that are retained later into life that result in DCC formation, hence the apparent small proportion of patients who experience the disease, but with an increase in third molar retention into the fourth decade of life and the incidence of third molar related caries rising then this is a situation that will only deteriorate further with more additional cost. By considering prophylactic third molar removal in this situation, we are not providing unnecessary treatment with an unnecessary financial cost to the NHS or independent funder. We are investing in an intervention that will reduce the global cost for treatment in an individual as well as the overall cost for the NHS. If left these patients will cost more to treat with possible ongoing costs. If the risk of Md2M DCC is high then removal of these retained third molars has a definitive cost-benefit for the patient and the NHS.

Conclusion

This study highlights the treatment outcomes for patients with third molar related DCC of the second molar and the potential costs for its management. DCC is an avoidable and preventable disease of the Md2M tooth. The risk of DCC forming on the second molar can be eliminated by the removal of the Md3M tooth before DCC occurs but this would involve the prophylactic removal of those third molars that pose this risk. The cost of preventing DCC on the Md2M tooth would still involve the cost of Md3M removal so the actual savings to be made in a management model that advocates prevention may be limited to the direct costs of managing the second molar tooth, the indirect costs to the patient in terms of loss of earnings and the intangible costs of pain and occlusal compromise: this would still be in the range of £3.6 m–£31.6 m per annum. However, if we continue to treat third molar teeth in isolation rather than consider patients as a whole, then these potential multiple treatment episodes will incur further unnecessary costs of multiple third molar removal. Potentially, this may, at the worst, double the cost to the NHS of third molar removal for each of these patients by another £14 m per annum.

The recent Montgomery v Lanarkshire Health Board determination regarding patients right to being informed of ' … any material risks' related to an intervention hold as equally as to being informed of the material risks of non-intervention.[21] Patients have the right to know what the potential outcomes of third molar retention are. Patients at risk of Md2M DCC should be informed of this potential and allowed to decide if their impacted third molar teeth should be removed.

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Diseases associated with mandibular third molar teeth

L. W. McArdle,*[1] M. Andiappan,[1] I. Khan,[1] J. Jones[2] and F. McDonald[3]

Key points

Provides awareness of the change in third molar disease as a consequence of NICE Guidance.	Highlights that an increase in caries is an indication for third molar removal.	Discusses increase in mandibular second molar tooth distal cervical caries in patients.

Aims To evaluate the clinical characteristics of mandibular third molar teeth (Md3M) requiring removal and to compare the characteristics of impacted Md3M with non-impacted Md3M. **Methods** One thousand and eleven patients who had 1,431 Md3M removed were evaluated. Features recorded included the age and gender of patients, the primary diagnosis indicating removal, the angulation and impaction status of the Md3M. **Results** The most common indications for Md3M removal were pericoronitis (49%), caries and related disease (C&RD) (27%), and distal cervical caries (DCC) of the mandibular second molar tooth (Md2M) (14%). The mean age of patients requiring removal of Md3M was 32.4 years. The mean age of patients, based on the angulation of impaction, were 28.6 years for vertical impaction, 30.1 years for mesio-angular impaction, 29.6 years for disto-angular impaction, 31.7 years for horizontal impacted and 41.6 years for non-impacted Md3M. The mean age of patients, based on the most common diseases were, 27.5 years for pericoronitis, 32.7 years for Md2M DCC, 36.1 years for C&RD, and 46.3 years for periodontal disease. Forty-one percent of all patients have Md3M removed due to disease related to dental caries with Md2M DCC accounting for 44% of all mesio-angular impacted Md3M removed. **Conclusion** Third molar disease varies according to the type of Md3M impaction. Impacted Md3M succumb to disease earlier than non-impacted Md3M. Pericoronitis remains the most common indication for impacted Md3M removal, however, C&RD and Md2M DCC have become more prevalent and are seen in older population groups. Md2M DCC is predominantly seen related to impacted mesio-angular third molars. Non-impacted Md3M, when indicated for removal, are generally removed in older patients due to C&RD and periodontal disease. The authors conclude that impacted third molars are more likely to be removed in younger patients due to pericoronitis while caries related disease (C&RD and Md2M DCC) is more common in older patient groups. With Md2M DCC accounting for 44% of all mesio-angular impacted Md3M being removed, consideration should be given to early intervention in the management of patients with mesio-angular impacted teeth.

Introduction

The eruption process for mandibular third molar teeth (Md3M) can result in two distinct end-points. Where present, many can erupt into a functional non-impacted position, however, many Md3M become impacted having failed to erupt into a functional position. Both impacted and non-impacted mandibular third molar teeth can succumb to, or contribute to, a variety of dental related diseases that can indicate the removal of the Md3M tooth.[1–4] Common Md3M diseases include pericoronitis; dental caries; caries related disease such as peri-apical infection; odontogenic cyst formation and periodontal disease. Md3M can contribute to and be a causative factor in the development of disease in mandibular second molar teeth (Md2M) such as distal cervical caries (DCC) or periodontal disease.[5–17] In addition, Md3M may also be removed to facilitate other forms of dental treatment such as orthodontics and orthognathic surgery.[3,4]

In 2000 the National Institute of Health & Clinical Excellence (NICE) introduced its guidance on the removal of wisdom teeth. Since then the profile of third molar disease has changed.[18] During the period of 1995–2010, the mean age of patients having third molars removed increased from 28 to 32 years, with an associated increase in the incidence of dental caries as the primary indication for the removal of third molar teeth by over 200%.[18–20]

This paper reports on a prospective cohort of 1011 patients attending for Md3M removal. The aims of the study were to determine the primary clinical indication for Md3M removal and to ascertain the variation and spectrum of disease based on the nature of impaction of the Md3M tooth. Both impacted Md3M and functional non-impacted Md3M were included in the study group cohort.

[1]Department of Oral Surgery, KCL Dental Institute, Guy's Hospital, London Bridge, London SE1 9RT; [2]Barts and The London, Institute of Dentistry; [3]Department of Postgraduate Dentistry, King's College London
*Correspondence to: Louis W. McArdle
Email: louis.mcardle@kcl.ac.uk

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Methodology

Data from 1011 patients attending for Md3M removal was collated longitudinally over a 2-year period from 2013–2015 and then retrospectively analysed. Patients were evaluated and the variables recorded were; age, gender, the eruption status of the Md3M, the primary clinical indication for the removal of the Md3M tooth, and the angulation of impaction of the Md3M.

The primary aim of the study was to determine the clinical diagnosis for Md3M removal centred on five year age cohorts of patients to determine if there was any age-related variation. Furthermore, to assess these clinical diagnoses in relation to the eruption and angulation of impaction of the Md3M and to determine any association with the age of patients.

The eruption status was defined as either unerupted, partially erupted, erupted or over-erupted. Any tooth that was detectable either visually or clinically with a periodontal probe was deemed exposed to the oral environment and consequently defined as partially erupted. Teeth with a visible occlusal surface but with a high distal gingival collar were also deemed partially erupted. Md3M, which were defined as erupted, had a complete gingival collar below the level of the maximum bulbosity of the crown and sitting in a vertical functional position on the level of the occlusal plane. The angulation of the Md3M was defined by convention as either vertical, mesio-angular, disto-angular, horizontal, or ectopic (ectopic was defined as all other possible angles of impaction distinct of the other four; for example, inverted.)

The primary diagnosis and clinical indication for Md3M removal was recorded but was not circumscribed: this was to permit any possible diagnoses to be recorded. Patients requiring Md3M removal due to pulpitis, dental abscess, peri-apical periodontitis, etc, where caries of the Md3M tooth was the promoter lesion for the development of these consequent diseases, were defined and recorded collectively as 'caries and related disease' (C&RD), as these diagnoses represent specific stages of the progression of dental caries. All subgroups of pericoronitis, such as acute, chronic, sub-acute and recurrent pericoronitis were grouped collectively into a single diagnosis of pericoronitis.

All patients attended either a primary care-based specialist oral surgery clinic, or a secondary care oral surgery department of a major teaching hospital. Treatment was carried out with either local anaesthesia, local anaesthesia and sedation, or day-case general anaesthesia.

Statistical analysis

Sample size was determined by power calculation and the sample and outcome characteristics were summarised using descriptive statistics. The comparison of Md3M subgroups for the disease variation and the Md3M angulations of impaction were carried out using Z test for proportions. The mean age of patients for different disease presentation and with impaction status were compared using one way ANOVA. Statistical significance was assumed at 5% level and all the analyses were carried out using SPSS version 23.0.

Results

Of the 1011 patients who were assessed, 604 (60%) were female and 407 (40%) male. In total, 591 patients had one Md3M removed and 420 patients had bilateral Md3M removed: a total of 1431 Md3M were removed. The number of Md3M present with no clinical indication for removal was 376, and 215 Md3M were clinically absent. The mean age of patients having Md3Ms removed was 32.4 years, (SD 11.5years, range 12–87 years).

Md3M characteristics and disease

The overall distribution of disease that indicated Md3M removal is shown in Table 1. Pericoronitis was the most common indication recorded accounting for 49% of all Md3M removed. C&RD for 27% of Md3M removed; Md2M DCC for 14%; periodontal disease for 5%, and dental/odontogenic cyst for 2%. Collectively, the remaining ten recorded diagnoses accounted for 4% of all diagnoses, and individually accounted for less than 1%. Caries combined, that is, C&RD and Md2M DCC, as an overall indication for removal of Md3M, accounted for the removal of 41% of all Md3M.

Of the 1431 Md3M removed, a total of 82% Md3M were impacted and 18% were vertical, non-impacted and in a functional position. Mesio-angular impacted Md3M accounted for 29% of the total removed, with horizontal Md3M impactions accounting for 14%; disto-angular Md3M impactions for 15%, and ectopic impactions for less than 1%. Vertically impacted Md3M accounted for 24% and 18% Md3M were vertical and non-impacted. (Table 2.)

If non-impacted Md3M are isolated from and compared with impacted Md3M then

Table 1 Primary diagnosis and distribution of all Md3M requiring removal

Diagnosis for removal	Number of Md3M removed	Percentage distribution (%)
1 – Pericoronitis	698	49%
2 – Caries & related disease (C&RD)	382	27%
3 – Md2M DCC	198	14%
4 – Periodontal disease	63	5%
5 – Dentigerous/odontogenic cyst	33	2%
6 – Prevention DCC second molar	18	1%
7 – Pre-orthognathic surgery	12	0.80%
8 – Food trap	9	0.60%
9 – External resorption of second molar	4	0.30%
10 – Prophylactic secondary to GA	4	0.30%
11 – Fractured tooth (not caries)	3	0.20%
12 – Pre-orthodontic	2	0.20%
13 – Pre-radiotherapy	2	0.10%
14 – Ramus bone graft pre-implant	1	0.10%
15 – Internal resorption	1	0.10%
16 – Non function	1	0.10%
Total number of Md3M removed	**1,431**	**100%**

Table 2 Primary diagnosis and distribution of Md3M requiring removal based on angulation and impaction

Primary diagnosis for removal of Md3M	Vertical impaction	Disto–ang impaction	Horizontal impaction	Mesio-ang impaction	Ectopic impaction	Vertical non-impacted
(N = 1,431)	N = 348 (24%)	N = 210 (15%)	N = 198 (14%)	N = 413 (29%)	N = 11(<1%)	N = 251 (18%)
Pericoronitis	271 (78%)	176 (84%)	106 (53%)	131 (32%)	6 (54%)	8 (3%)
C&RD	56 (16%)	26 (12%)	22 (11%)	62 (15%)	Nil	213 (85%)
Md2M DCC	Nil	Nil	18 (9%)	180 (44%)	Nil	Nil
Periodontal disease	2 (<1%)	3 (1.5%)	25 (13%)	13 (3%)	Nil	22 (9%)
Dentigerous/odontogenic cyst	4 (1%)	4 (2%)	16 (8%)	5 (1%)	4 (36%)	Nil
Prevention DCC second molar	Nil	Nil	3 (1%)	14 (3%)	Nil	Nil
Pre-orthodontic/ orthognathic surgery	Nil	Nil	4 (2%)	6 (1%)	Nil	Nil
All other indications total	15 (<5%)	1 (<1%)	4 (2%)	2 (<1%)	1 (9%)	8 (<4)%

the distribution of disease can be considered comparatively. Pericoronitis accounted for the removal of 58% of impacted Md3M compared with 3% of non-impacted Md3M (P <0.0001), C&RD for 14% of impacted teeth compared with 84% of non-impacted teeth (P <0.0001), Md2M DCC for 17% of impacted teeth and 0% of non-impacted teeth (P <0.0001), periodontal disease for 4% of impacted teeth and 9% of non-impacted teeth (P <0.001), and finally dental/odontogenic cyst for 3% of impacted teeth compared with 0% non-impacted (P <0.01).

The most common eruption status for Md3M requiring removal was that of partial eruption, which totalled 1133 Md3M (79%). Erupted teeth accounted for 251 Md3M removed (18%); unerupted teeth accounted for 43 Md3M (3%), and four Md3M were over-erupted (<1%).

Md3M disease diagnoses and angulations

Disease diagnoses in relation to the angulation and impaction of the Md3M were also considered and are presented in Table 2 and Figure 1.

Of the most common diseases, pericoronitis accounted for the removal of 32% of all mesio-angular Md3M compared with 84% of all disto-angular Md3M (P <0.001); 78% of all vertical impactions (P <0.001); 53% of all horizontal Md3M (P <0.001) and 3% of vertical non-impacted teeth (P <0.001).

In contrast C&RD accounted for the removal of 15% of mesio-angular Md3M compared with 12% of disto-angular Md3M (P = 0.4), 16% of all vertical Md3M (P = 0.7), 11% of horizontal Md3M (P = 0.2), but 85% of vertical non-impacted teeth (P <0.001). DCC of the Md2M accounted for the removal of 44% of all mesio-angular Md3M and 9% of horizontal Md3M (P <0.001) but was not recorded in any of the other groups (P <0.001).

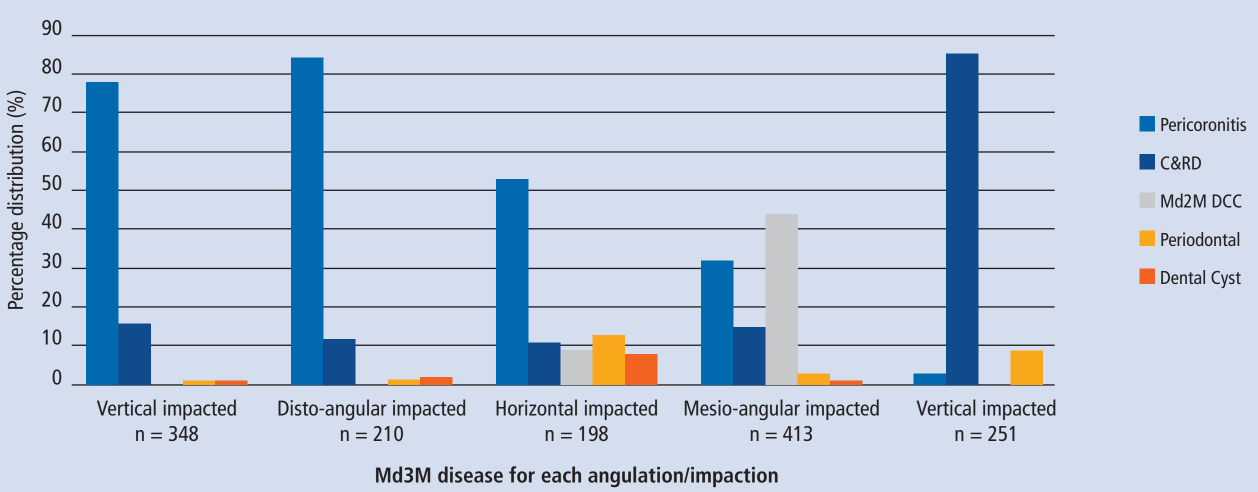
Periodontal disease accounted for the removal of 13% of all horizontal impacted Md3M compared with 3% of mesio-angular Md3M (P <0.001); 1.5% of disto-angular Md3M (P <0.001); 9% of vertical non-impacted Md3M (P = 0.18) and less than 1% of vertical impacted Md3M (P <0.001).

The variation of disease seen in the differing types of impaction suggests that certain diseases, such as Md2M DCC, occur dependent upon the angulation of impaction and other disease, such as C&RD, independent of the angulation.

Mean age, impaction status & disease

The mean age of patients having Md3Ms removed was 32.4 years (range 12–87 years, SD: 11.5 years). In addition, the mean age of patients, based on the impaction status of the Md3M was

Fig 1 Percentage distribution of main Md3M diseases based on angulation impaction status



calculated (Fig. 2) and the mean age of patients based on the most common diagnoses (Fig. 3).

For patients having a mesio-angular Md3M removed, the mean age of patients was 30.1 years (range 12–67 years, SD: 7.7 years); for disto-angular Md3M impactions, the mean age was 29.6 years (range 19–86 years, SD: 8.3 years); for horizontal Md3M impactions– 31.8 years, (range 14–87 years, SD: 10.3 years); for vertical Md3M impactions – 28.6 years, (range 16–57 years, SD: 7.5 years); for vertical non-impacted Md3M 41.6 years, (range 17–83 years, SD: 15.6 years); and for ectopic impactions the mean age was 31.3 years, (range 18–45 years, SD 9.6 years). For reference, the Office for National Statistics in the UK report that the mean age of the UK population is 40.9 years.[21]

In terms of disease, for the most common diagnoses related to patients having a Md3M removed, the mean age of patients with a diagnosis of pericoronitis was 27.5 years (range 16–70 years, SD: 5.8 years); for C&RD, the mean age was 36.1 years (range 17–86 years, SD: 13.3 years); for periodontal disease, 46.3 years, (range 24–81 years, SD: 13.6 years); for Md2M DCC, 32.7 years, (range 21–55 years, SD: 7.3 years); and for dentigerous/odontogenic cyst, 43.1 years, (range 14–87 years, SD: 16.4 years). In relation to vertical impacted and non-impacted Md3M with a diagnosis of C&RD, the mean age of patients with a vertically impacted third molar was 31.9 years (range 19–65 years, SD: 9.6 years) and for a vertically non-impacted third molar it was 39.7 years (range 17–83 years, SD: 14.7 years).

Discussion

The spectrum of disease and impactions

This study, as with other reported studies, reports pericoronitis as the most common indication for Md3M removal, with dental caries, cyst formation and periodontal disease being other common diseases associated with Md3M.[22,23] The scope of impacted Md3M angulations in this study is similar to other studies.[22–24] Most Md3M studies do not, however, emphasise whether non-impacted Md3M are included in individual case-series or whether they have been incorporated as vertical impacted Md3M. The spectrum of disease related to non-impacted Md3M in this study is significantly different to the disease spectrum for impacted teeth and in a significantly older population (P <0.001).

When considering the disease spectrum of Md3M, it is important to consider Md3M disease in relation to each type of Md3M impaction rather than produce a summative account for all Md3M. By categorising disease in relation to Md3M impaction, we can reflect on the clinical significance that the nature of impaction may have on the potential disease outcome for patients.

Pericoronitis

Pericoronitis is the most common indication for the removal of Md3M as a whole (49%), but where it accounts for only 3% of non-impacted vertical Md3M, it accounts for 32% of mesio-angular Md3M, 53% of horizontal impactions, 78% of vertical impaction and 84% of disto-angular impactions (P <0.001) (Fig. 1). The reasons for the variation in pericoronitis related to the differing types of impaction may be explained by the local anatomy and the presence of an operculum of mucosa overlying the occlusal surface of vertical and disto-angular impactions. This would create a local environment conducive to local soft tissue infections secondary to poor or inadequate oral hygiene. Due to the inclination of a mesio-angular Md3M this would tend to elevate the distal aspect of the crown away from the soft tissues eliminating the operculum and exposing the distal surface, which may then be more accessible to oral hygiene and reduce risk of pericoronitis.

Caries and related disease

C&RD accounts for 27% of all Md3M extractions with C&RD in each of the main categories of impacted Md3M comparatively uniform. C&RD accounted for 15% of mesio-angular impactions, 12% of disto-angular impactions, 11% horizontal impactions and 16% of vertical impactions were removed due to C&RD. This suggests that the diagnosis and incidence of C&RD is independent of the type of Md3M impaction. However, compared with impacted Md3M, C&RD accounts for 85% of all non-impacted vertical Md3M removal (P <0.001) (Fig. 1). Md3M C&RD has been shown to increase with age and vertical, non-impacted Md3M tend not to be associated with the common diseases of impaction such as pericoronitis (P <0.001). In older middle-aged patient groups with retained Md3M, non-impacted vertical third molars are more common than

Fig. 2 Mean age of patients requiring Md3M removal based on Md3M angulation and impaction

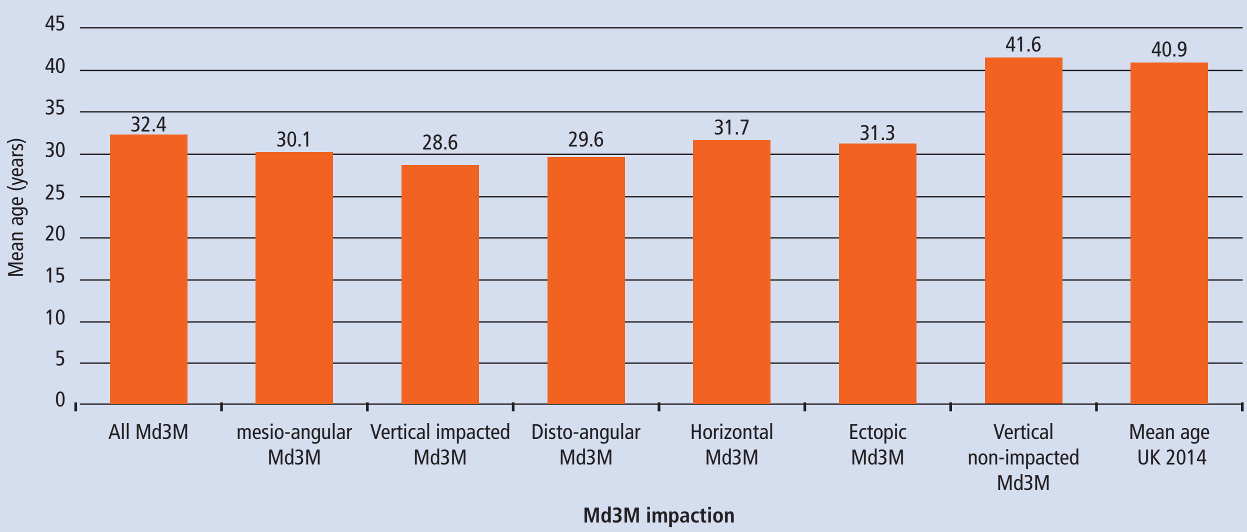
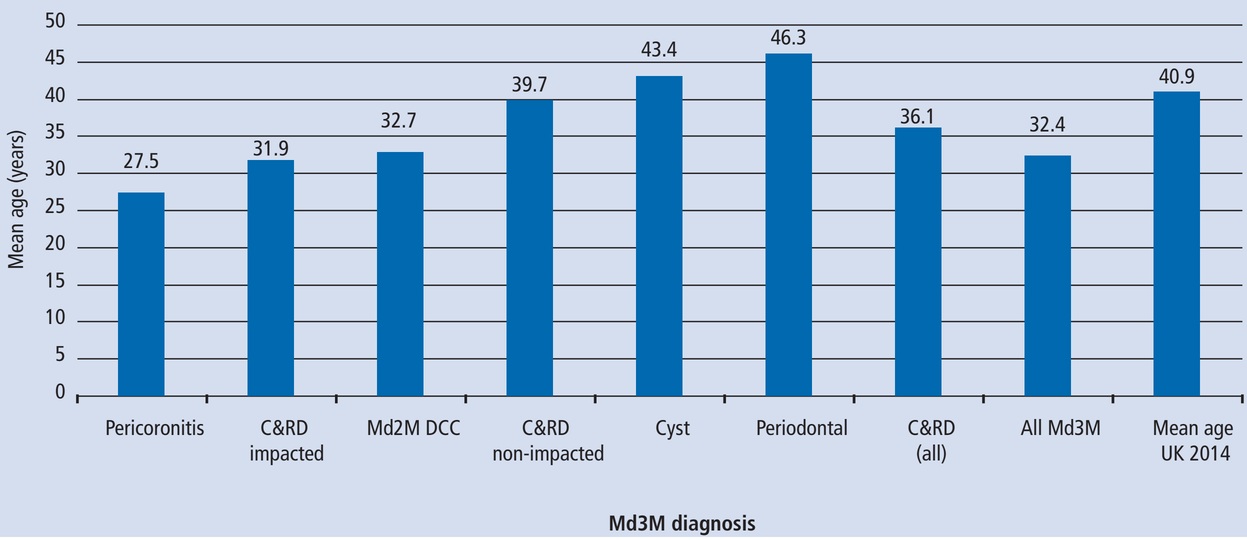


Fig 3 Mean age of patients requiring Md3M removal based on Md3M diagnosis



impacted third molars.[25] A non-impacted Md3M would not be excluded from the potential of experiencing dental disease at some point but most would remain functional and disease free for a period of time before a proportion of them succumb to dental disease such as caries and periodontal disease as reported here. This is supported by the observation that the mean age of patients with impacted Md3M with C&RD compared with non-impacted Md3M with C&RD is 31.9 years compared with 39.7 years respectively (P <0.001).

Md2M DCC

Md2M DCC, as an indication for Md3M removal, has been reported as contributing a relatively small proportion of Md3M removal in older studies.[5,22,–24] In this series it is not associated with vertical, disto-angular or ectopic impactions and its significance should not be considered collectively with all other types of Md3M impactions.

Md2M DCC in this study accounts for 14% of all Md3M removed and 17% of all impacted Md3M removed. It accounts for 9% of all horizontal impactions, however, Md2M DCC accounts for 44% of all mesio-angular Md3M removed.

The mean age of patients with Md2M DCC is 32.7 years compared with patients with pericoronitis (27.5 years) (P = 0), with pericoronitis being the most common reason for Md3M removal. In this case series over 50% of all Md3M are removed in patients between 20–29 years of age suggesting that the majority of patients who will require Md3M removal will have lost them by the time they are 30 years old. This corroborates that Md2M DCC is a disease of older patients and, as pericoronitis is the most common indication for impacted Md3M removal, patients will generally succumb to other forms of disease such as this before Md2M DCC can occur.

In addition to the loss of the Md3M to facilitate treatment of Md2M DCC, it has been reported that Md2M DCC has significant financial costs attributed to it and results in the eventual loss of 40% of Md2M.[26] The primary risk factor related to Md2M DCC formation is the partially erupted mesio-angular or horizontally impacted Md3M and with such a high incidence of Md2M DCC in mesio-angular impactions, consideration should be given to this disease's potential.

NICE advocated the proscription of prophylactic third molar removal in the late 1990s and the change in patient management had resulted in the mean age of patients requiring third molar removal increasing to 32 years by 2009/10, with 30% of third molars removed due to dental caries as the primary indication for removal.[18] This data could not differentiate between third molar caries and Md2M DCC, however, in this present study Md3M C&RD accounted for 14% of all impacted Md3M removed and Md2M DCC for 17% of impacted Md3M removed: in total 31% of all impacted Md3M were removed due to all categories of caries disease. With the addition of non-impacted Md3M C&RD, a total of 41% of Md3M were removed due to caries. Md2M DCC is the most common indication in this case series for the removal of a mesio-angular Md3M.

As 44% of all mesio-angular and 9% of horizontal Md3M removed due to Md2M DCC this qualifies concern that observing and retaining mesio-angular Md3M, in particular, until disease occurs, may be an unsound management strategy. Contrary to NICE guidance, early removal of mesio-angular and horizontal Md3M may be indicated and should be considered so as to avoid the consequences of Md2M DCC.

Periodontal disease

Periodontal disease accounts for only 5% of all Md3M removed in this case series, however, it should be noted that only the primary indication for Md3M was recorded as opposed to all concomitant diseases that may have been associated with a particular Md3M. Nonetheless, periodontal disease was the primary indication for 12% of all horizontal, 9% of all vertical non-impacted Md3M, with smaller proportions for all other impacted teeth. Periodontal disease is generally a quiescent disease that patients are often unaware of and generally only gives rise to significant symptoms in the later stages of the disease. Periodontal disease has been reported to be a clinical finding related to impacted third molars,[13–17] however, this data does not contradict these studies but may suggest that Md3M will become symptomatic and succumb to other Md3M diseases before periodontal disease becomes symptomatic and then the prime indicator for intervention.

Other disease

All the remaining indications for Md3M removal collectively accounted for 4% of all indications and less than 1% individually. Some of these indications for third molar removal are interventional to facilitate other forms of treatment such as orthodontics, orthognathic and dental implant treatment, others are uncommon such as internal or external resorption and others may be very weak indicators for removal, such as food packing. Food packing, and similar diagnoses, should not be dismissed as an indication for Md3M removal as these types of problems can be a constant source of irritation to a patient and the preference of the patient for the removal of the offending tooth is as valid a treatment option than any. Although a small number: 18 (1%) of Md3M were removed for the prevention of Md2M DCC, consideration has to be given to the weight of evidence for the potential for this disease to occur and for patients to be able to consider the options of intervening early or monitoring accordingly.

Age and diagnoses

The mean age of patients requiring third molar removal was 32.4 years, however, there was marked variation of patients' mean age based upon diagnoses. One-way ANOVA test was used to compare the mean ages of patients based on the most common diseases. Pericoronitis, with a mean age of patients being 27.5 years; C&RD mean age 36.1 years; and Md2M DCC, mean age 32.7 years, when compared individually with each other, showed a statistically significant relationship ($P = 0$).

The eruption of Md3M is generally accepted to occur between the ages of 18–24 years and the timing of disease presentation varies. Pericoronitis occurs frequently and relatively soon after failed eruption of the Md3M; it is the most common disease associated with impacted Md3M and in general occurs in younger age groups. Caries, in comparison, is a disease that will take time to develop before significant clinical signs and symptoms become present. As an indication for Md3M removal, C&RD occurs on average in older age groups than pericoronitis. Likewise, Md2M DCC tends to occur in older patient groups but only with those with a mesio-angular or horizontal impacted Md3M.

Primary v secondary disease

The primary consequence of third molar impaction is the failure of the occlusion to reach the endpoint of maturity with the resultant dental malocclusion at the posterior aspect of the dental arch. An impacted tooth is a developmental anomaly and is defined as a disease by the WHO within the ICD10 classifications of diseases (K011).[27] Impaction is often overlooked as a disease in itself and the focus of defining third molar disease is often given to the consequent diseases of Md3M impaction, such as pericoronitis. However, the primary disease affecting the third molar is the impaction of the tooth and it is this which can then lead to consequential diseases such as pericoronitis, etc. These consequential diseases will generally occur secondary to the impaction, with patients experiencing a variety of differing disease. Where the third molar is erupted and functional, disease will not occur in the same manner as an impacted tooth. We should acknowledge that the impaction of the third molar is the primary disease that can then contribute to the development of secondary disease. Only in the non-impacted Md3M can we consider that caries, periodontal disease, etc, are the primary disease.

Variation in the characteristics of the Md3M contributes to when disease may occur and the type of disease that may occur. The capacity to understand the potential and the ability to anticipate third molar disease should guide clinical judgement in the management of patients. Understanding the spectrum and nature of disease in relation to impacted Md3M should allow better management of individual patients with impacted Md3M. Patients with third molars cannot be managed as a collective group as this can have negative outcomes, especially in relation to diseases such as Md2M DCC.

The prevalence of impacted third molars in the general population as a whole has been reported to be approximately 25%.[28] This figure is misleading as it would appear to include everyone, including people who have had third molars removed. This miscalculates the true prevalence as it mistakenly presumes that if a patient has no third molars that the never had any previously. It has been reported that the prevalence of impacted third molars in the 20-30 age group is over 70%.[29] It has also been reported that for those patients in middle-age only 13% retain an impacted Md3M.[26] Although these two later studies are not related, if these studies are representative of patients then 80% of patients with impacted third molars will have undergone third molar removal by the time they are middle-aged. With such a high potential proportion of the adult population requiring third molar removal, consideration should be given to addressing the potential for secondary disease rather than solely addressing secondary disease when it occurs.

Conclusions

Md3M can display a wide spectrum of disease that varies and is dependent on the type of Md3M impaction. Disease occurs in non-impacted Md3M as well as impacted Md3M with diseases affecting non-impacted teeth tending to be the typical dental diseases of caries and periodontal disease, and in an older population. Diseases related to impacted teeth reflect the more specific diagnoses of pericoronitis, Md3M caries and and Md2M DCC, and in a younger population.

The variation of disease and the mean-age of patients seen in the differing types of impaction is significant in that some diseases, such as Md2M DCC, will occur dependent upon the angulation of impaction, and others, such as C&RD, independent of the angulation. Younger patients are more affected by disease such as pericoronitis and less so by other diseases such as C&RD, whereas older patients are more affected by C&RD and Md2M DCC.

Md2M DCC accounts for 44% of all mesio-angular impacted and 9% of horizontally impacted Md3M removed. The risk factors for the development of Md2M DCC have been previously reported.[5–12] NICE guidance is flawed and early intervention in patients with impacted Md3M at risk of causing Md2M DCC should be considered and prophylactic intervention has a role to play in the management of patients.

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Characteristics of disease related to mesio-angular mandibular third molar teeth

L.W. McArdle[a,*], J. Jones[b], F. McDonald[c]

[a] Department of Oral Surgery, KCL, Faculty of Dentistry, Oral & Craniofacial Sciences, Guy's Hospital, London Bridge, London SE1 9RT
[b] Department of Oral Surgery, QMUL Institute of Dentistry, Bart's & The London School of Medicine & Dentistry, London E1 2AD
[c] Department of Orthodontics, KCL, Faculty of Dentistry, Ora & Craniofacial Sciences, Guy's Hospital, London Bridge, London SE1 9RT

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Abstract

The aim of this study was to identify the indications for the removal of mesio-angular mandibular third molars based on age and dental health as measured by the DMFT (decayed, missing, and filled teeth) score, and to find out if early intervention should be considered. We studied 319 patients who had 431 mesio-angular mandibular third molars removed. Variables recorded were age, primary indication for removal, and the DMFT score. Indications for removal included distal cervical caries (DCC) in the mandibular second molar (n = 180, 44%), pericoronitis (n = 131, 32%), and caries and related disease (n = 62, 15%). The frequency of distal cervical caries (DCC) in the mandibular second molar increased linearly as patients became older and was the most common reason why mesio-angular third molar teeth were removed. This suggests that patients should be advised of the consequences of retaining these types of third molars, and offered prophylactic removal of asymptomatic teeth.

Keywords: oral surgery; third molar; disease

Introduction

Mesio-angular impaction of mandibular third molars (maMd3M) is the most common type of impaction, and can contribute to a variety of common disorders such as pericoronitis, dental caries, and periodontal disease.[1–3] More importantly, mesio-angular mandibular third molars that are partially erupted can cause distal cervical caries (DCC) in the second molar, which can have serious consequences.[4–12] A recent study suggested that this accounts for the loss of up to 40% of second molars, with the remaining 60% requiring restoration.[1] Its incidence varies from 2% – 14% of patients who have third molars removed, but these figures relate to all categories of teeth rather than to specific types of impaction.[3,5,13–16]

If all, or a large proportion of, partially-erupted third molars lead to DCC in the adjacent tooth, then early intervention and prophylactic removal of the third molar should be considered because the risk of retention could outweigh the cost of early removal.[12] If this is the case, then the National Institute for Health and Care Excellence (NICE) guidance may be in conflict with the reality of retention (particularly of mesio-angular mandibular third molars) because of the risk they pose. However, as we cannot tell which patients will be affected, early intervention must still be questioned.

Our aim therefore was to study the characteristics of patients who had mesio-angular mandibular third molars removed, and to establish whether early intervention should be considered.

* Corresponding author. Tel.: 020 7188 4345; Fax: 020 7188 4360.
E-mail address: louis.mcardle@kcl.ac.uk (L.W. McArdle).

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Method

As part of a larger study, we collated and retrospectively assessed data on 1011 patients who had mandibular third molars removed over a two-year period (January 2013–January 2015).[3] The variables recorded were age, sex, angulation of the impacted tooth, primary indication for its removal, and the DMFT score as a basic measurement of dental health.The primary aim of the present study was to identify the indications for the removal of mesio-angular teeth in patients grouped according to age (five-year age groups), to find out if the disease varied, and to consider the diagnoses in relation to their dental health as measured by the DMFT score.

A total of 319 patients had mesio-angular teeth removed (mesial inclination related to the perpendicular of the occlusal plane). “Pericoronitis” referred to all variants of the condition, and “caries and related disease” to all teeth that were removed because of, or as a consequence of, dental caries.

Statistical analysis

The original sample size was calculated by a power calculator (Gpower 3.1.5, Universität Düsseldorf), which allowed for a CI of 95% with a 5% margin of error (standard power level of 80% and alpha level of $p = 0.05$). A sample size of 969 was calculated, but 1011 patients were ultimately assessed.

The sample and outcome characteristics were summarised using descriptive statistics. The mean age of the patients for different diseases and type of impaction were compared using one-way ANOVA. Significance was assumed at the 5% level, and analyses were done with the help of IBM SPSS Statistics for Windows, version 23.0 (IBM Corp).

Results

A total of 319 patients had 413 mesio-angular mandibular third molars removed (225 unilateral and 94 bilateral). The mean age of all the patients was 30.1 years ($n = 319$, SD:7.7 years, range 12-67 years).

Table 1 shows the indications for removal. DCC in the second molar, pericoronitis, caries and related disease, odontogenic cyst, and periodontal disease, were defined as the principal indicators because they were the most common and most important. These only were included in the descriptive analyses, as the incidence of the others, when spread across the age groups, was not significant.

Age and disease

Fig. 1 shows the mean age of patients who required the removal of teeth by principal diagnoses. For the most common diseases, the mean age varied with the type of disease. Patients who had pericoronitis were significantly younger than those with caries or those with DCC in the second molar ($p < 0001$).

Table 1
Disease/principal indications for removal of 413 mesio-angular mandibular third molars (MAMd3M) (225 unilateral and 94 bilateral) in 319 patients.

	Diagnosis for removal of MAMd3M	No. (%) removed
1	Distal caries in the mandibular second molar (Md2M DCC)	180 (44)
2	Pericoronitis	131 (32)
3	Caries & related disease (C&RD)	62 (15)
4	Periodontal disease	13 (3)
5	Prevention of distal cervical caries in the second molar	14 (3)
6	Odontogenic cyst	5 (1)
7	Preorthodontic/orthognathic treatment	5 (1)
8	External resorption of second molar	2 (<1)
9	Prophylactic secondary to GA	1(<1)
	Total number removed	413

DMFT

To allow comparison with the 2009 Adult Dental Health Survey (ADHS), the mean DMFT score was calculated for 10-year age ranges of patients who had mesio-angular mandibular third molars removed because of pericoronitis, DCC in the second molar, and caries and related disease (Fig. 2).[17] The mean score based on these most common diseases was comparable with each disease but roughly 50% lower than the ADHS for each of the 10-year age ranges. The only exception to this was patients aged between 45 and 54 years who had caries and related disease. In this group it was comparable to that in the ADHS 2009. The mean DMFT scores of patients from the main database of 1011 patients also showed a DMFT that was 50% lower than the ADHS for each of the 10-year age ranges.[3]

Disease distribution

Fig. 3 shows the most common indications for the removal of mesio-angular mandibular third molars by age group. Other indications constituted a small proportion of patients and offered no descriptive analyses. The age range of all the patients was 12-67 years, and that of those with the principal diseases was 17-67 years (a 67-year-old patient had one tooth removed but this is not shown on the graph).

In the younger age groups, pericoronitis was the most common reason for removal, and accounted for 78% of all the teeth removed in those aged 15-19 years ($n = 18/23$ teeth); 55% in those aged 20-24 ($n = 39/71$ teeth); 41% in those aged 25-29 ($n = 55/134$), and 14% in those aged 30-34 ($n = 13/93$).

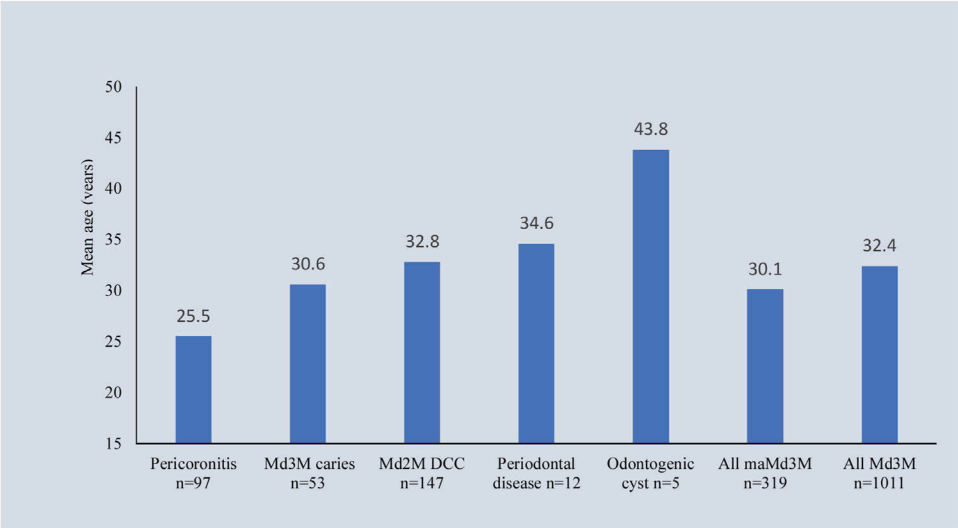

Fig. 1. Mean age (years) of patients requiring removal of mesio-angular mandibular third molars (MAMd3M) based on principal diagnoses. The graph shows that for the most common diseases, the mean age of patients who had MAMd3M removed varied with the type of disease. Patients who had pericoronitis were significantly younger than patients with Md3M caries ($p < 0.001$; df 149, $F = 21.8$) or those with distal cervical caries in the second mandibular molar (Md2M DCC) ($p < 0001$; df 243, $F = 74.5$).

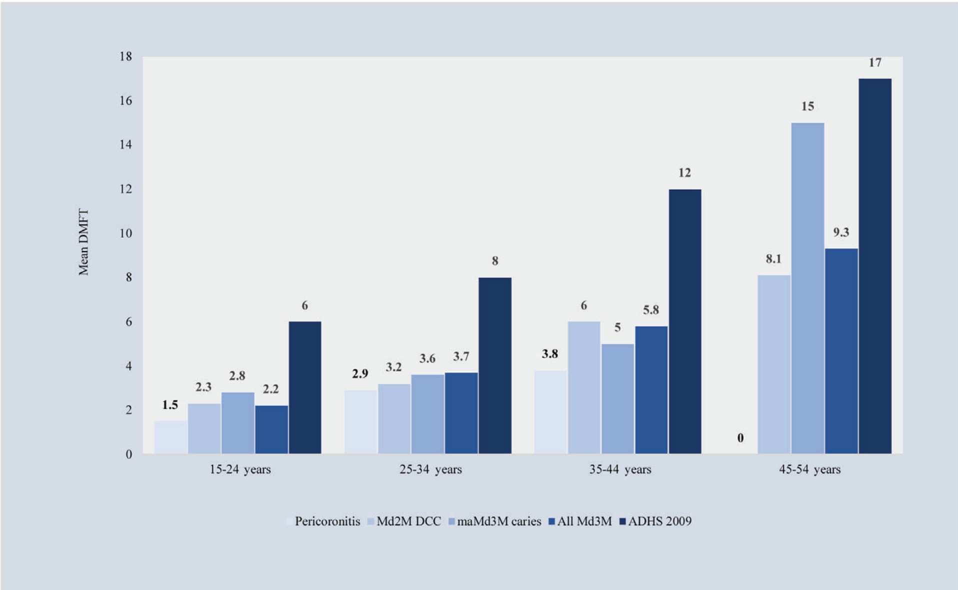

Fig. 2. Mean decayed, missing, filled teeth (DMFT) scores for patients who had mesio-angular mandibular third molars (MAMd3M) removed, based on principal diagnoses, and compared with all third molars (Md3M) removed and the results of the Adult Dental Health Survey (ADHS) 2009[3,17] (Md2M DCC = distal cervical caries in the mandibular second molar). For the most common diseases, the mean DMF of patients who had MAMd3M removed was comparable with all patients requiring removal of Md3M, though approximately 50% lower than the AHDS 2009 for comparable age groups.

The incidence of caries and related disease ranged from 10% - 20% in all age groups. No patients under the age of 20 had DCC in the second molar, but it was the primary indication for the removal of mesio-angular mandibular third molars in 21% of those aged 20-24 (n = 15/71 teeth), 35% of those aged 25-29 (n = 47/134 teeth), and 68% of those aged 30-34 (n = 63/93 teeth). In each of the older age groups the proportion removed was generally over 60%, but the total number of patients in each of these groups decreased with age, as fewer third molars are retained into older age.

Discussion

The diseases that contribute to the removal of third molars are generally reported independent of the type of

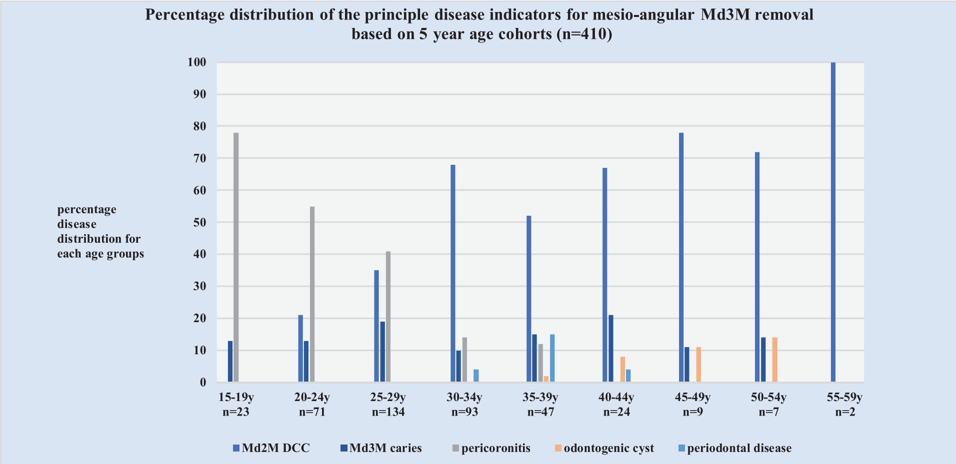

Fig. 3. Percentage distribution of principal disease indicators for removal of mesio-angular mandibular third molars (MAMd3M) based on five-year age groups. A total of 413 teeth were removed from 319 patients. Other indicators constituted a small number of patients and offered no descriptive analysis and are not shown on the graph. Overall, ages ranged from 12 to 67 years, and for those with principal disease indicators from 17 to 67 years one patient under 15 years had 2 MAMd3M removed for orthodontic reasons and a 67-year-old patient had one MAMd3M removed but these are not included on the graph) (Md2M DCC = distal cervical caries in the mandibular second molar; Md3M C&RD = caries and related disease in the mandibular third molar).

impaction,[1,15,18–20] which gives a comprehensive illustration of the disease, but does not show the effect of variables such as age and type of impaction. Our study solely evaluated disease in patients with mesio-angular mandibular third molar teeth.

Pericoronitis is commonly reported to be the main indication for the removal of mandibular third molars and those that are mesio-angular,[1,3,15,20] but in our study, most were removed because of DCC in the second molar (44%). A previous study reported that as the mean age of the third-molar patients increased, caries and its variants (C&RD) become the most common primary reason for removal.[21] The large incidence of DCC in this group also reflects the fact that those having third molars removed are now older than previously reported, and present with a different spectrum of disease.

The mean age of patients with pericoronitis (25.5 years compared with 30.6 years for caries and related disease: $p < 0.0001$; df 149; $F = 21.8$, and 32.8 years for DCC in the second molar: $p < 0.0001$; df 243; $F = 74.5$) confirms that it is a disease of younger patients (Fig. 1). From the data, 55% of all mesio-angular third molars were removed before the age of 30 years, and pericoronitis was the most common reason (49%). In comparison, DCC in the adjacent second molar tooth accounted for 27% of the teeth removed in patients under 30, and for 65% of those removed in older patients. Pericoronitis accounted for only 10% of all the teeth removed in those over 30, with most of these being in the 30-34 age range (Fig. 1). Caries and related disease accounted for roughly 15% of all the teeth removed, and the incidence remained relatively uniform across the age groups (range 10% - 20%). The increasing frequency of DCC in the mandibular second molar as patients become older has previously been suggested,[6,16] but these studies did not reflect or compare their results with other clinical indications, or did not have comparable age groups. It is noteworthy that in this study the frequency of caries and related disease remained relatively constant in each of the age groups, but the frequency of DCC in the adjacent tooth increased, even though both diagnoses are caries.

Most mesio-angular mandibular third molars are removed before the age of 30 years whilst the number of older people retaining them decreases. It is this group that may have problems with DCC in the adjacent second molar. As patients become older, the frequency of pericoronitis as the main reason for removal declines, but conversely DCC increases (Fig. 2). Most patients with a mesio-angular mandibular third molar will have it removed due to pericoronitis when younger, before the potential for DCC in the second molar can be realised. Those patients who retain their mesio-angular mandibular third molars into later life are at significant risk of developing DCC in the adjacent second molar. The reason why we do not always find it is because a large proportion of mesio-angular teeth are removed before it can occur.

It has been reported that the mean DMFT scores of patients with DCC in the second molar were roughly 50% lower than those of comparable age groups in the ADHS 2009.[4,5] This suggested that patients with low scores may be more likely to have DCC, as low scores suggest better oral hygiene, a reduced likelihood of pericoronitis, and consequent retention of the mesio-angular mandibular molar into later life. In our study the mean DMFT scores for patients with DCC were also 50% lower than those in the 2009 ADHS, as were the mean DMFT scores for patients with the other main types of disease associated with mesio-angular mandibular third molars (Fig. 1). In addition, the mean DMFT scores for all patients having mandibular third molars removed was also roughly 50% less than the comparable age ranges from the ADHS 2009.[4] Good dental health, as measured by the DMFT score cannot therefore be used as a predictor of any specific disease in people with mesio-angular mandibular third molars. It suggests instead that all patients with partially-erupted mandibular third molars are at risk of disease, and not that patients with better dental health are more or less prone. Low scores cannot, therefore, be used to refute the possibility of future problems with impacted third molar teeth.

The relative incidence of DCC in patients who require removal of a third molar has been reported to be between 4% and 14%.[3,5,13–16] These figures, however, include all types of impaction and disguise the fact that DCC primarily affects patients with mesio-angular mandibular third molars. Horizontal mandibular third molars are also associated, but the incidence is only 9%.[3] The inclusion of patients with other types of impactions that do not contribute to DCC of the second molar dilutes the clinical significance, and it would be inappropriate to base the widespread prophylactic removal of all third molars on such a small proportion of patients. However, as 44% of all mesio-angular third molars, and 65% of those in patients over 30 years of age, are removed because of DCC, then prophylactic intervention may be helpful in patients with partially erupted mesio-angular mandibular third molar teeth.

In most cases, third molar disease will principally affect the third molar tooth alone. In such cases, leaving it until disease occurs may be appropriate, but the prevention of DCC must be considered for those patients with mesio-angular mandibular third molars. Watchful waiting and radiographic observation are pointless, as once the disease has occurred, it is too late.[12,22] If the potential for DCC to develop is significant, then it reopens the debate about early intervention and prophylactic removal of third molars, specifically those that are mesio-angularly impacted.

The results of this study suggest that it is becoming easier to qualify and quantify the relative risks of mandibular second molar DCC. NICE relies on the outcomes of randomised controlled trials to determine healthcare policy and guidance,[23] but this level of evidence to support or refute prophylactic removal does not exist, and clinical trials to measure the results of retention would be unethical. Case series such as these are often discarded because of potential bias, but they are the best that are available.

The NICE guidance advises against the removal of disease-free impacted third molars, stating that there is no reliable evidence to support any benefit to health.[24] However, retention of mesio-angular mandibular third molars risks the formation of DCC in the second molar and its development can result in the loss of 40% of second molars.[12] Early intervention should be considered in the management of these patients and will involve removal of the third molar, or coronectomy, where there is a high risk of injury to the inferior dental nerve.

Conclusion

We recommended that all patients with asymptomatic, partially-erupted mesio-angular mandibular third molar teeth are informed of the relative risks of long-term retention and the development of DCC in the adjacent second molar, and that consideration is given to the early, prophylactic removal of mesio-angular mandibular third molars when appropriate.

Conflict of interest

We have no conflicts of interest.

Ethics statement/confirmation of patients' permission

Ethics advice was sought and deemed not to be required. Patients' permission not required.

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